71st Congress, 3d Session | SENATE | Document No. 308

NATIONAL HYDRAULIC LABORATORY

PROGRESS REPORT

DESIGNS, ESTIMATES OF COST AND COMPARISONS OF DESIGNS

RELATING TO

THE NATIONAL HYDRAULIC LABORATORY AT THE UNITED STATES BUREAU OF STANDARDS, WASHINGTON, D. C., PREPARED BY JOHN R. FREEMAN, CONSULTING ENGINEER PROVIDENCE, R. I.

[Supplemental to Senate Document No. 208]

PRESENTED BY MR. HEBERT

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PROGRESS REPORT ON NATIONAL HYDRAULIC LABORATORY

PROVIDENCE, R. I., *February 24, 1931.*

Hon. JOSEPH E. RANSDELL,
Hon. FELIX HEBERT,
United States Senators,
Senate Office Building, Washington, D. C.

GENTLEMEN: I appreciate your interest and desire to learn of progress of the national hydraulic laboratory, for which a few months ago Congress appropriated $350,000.

Much progress has been made by the staff of the Bureau of Standards in preparing plans, which it was hoped would be ready to submit to contractors for bids early in March, but I regret to report that these plans, so far as developed up to a few days ago, *will not give a laboratory that can fulfill the promises* which I made in the various hearings before Congress from 1922 to 1929, about useful *large-scale* fundamental research for improving the economy and accuracy of measurements of water by weirs, orifices, etc., nor has adequate provision yet been made for fundamental research concerning the hydraulic laws governing the flow of water in channels of various shapes at various velocities and slopes.

The Bureau's plans now nearing completion will nevertheless provide a laboratory in which a vast amount of useful work can be done, covering perhaps nine-tenths of the problems likely to be presented, and will give a laboratory generally comparable in scope with the best existing laboratories in Europe and America, excepting one or two of the recent European laboratories, notably the new laboratory at Obernach, near Munich, *to which it probably will be decidedly inferior* in precision of measurement for large-scale work.

This Obernach laboratory was promoted by some of the foremost European engineers, largely for testing out scale effect and for testing the accuracy with which the so-called doctrine of similitude, as used in experiments with extremely small models will be confirmed by experiments on much larger models, or with the behavior of the actual hydraulic structure.

These European hydraulic laboratories have each cost very much less than the sum provided for building this American national laboratory, but each has had the great advantage of being designed by an engineer of large practical experience. They have been graduallv developed step by step during the past 20 years. The vast majority of researches on flow of water by means of models and the doctrine of hydraulic similitudes are best tried out in their preliminary stages with discharge of water seldom exceeding 5 cubic feet of water per second. The laboratory proposed by the Bureau staff can handle up to 250 cubic feet per second or double that in any of the European laboratories, but apparently will fail *in precision of measurement of large quantities*, and in opportunity for fundamental research in general fiields of great importance to the designers of large hydraulic works

By a skillful use of the congressional appropriation of $350,000, it was entirely possible to have had here in Washington a national hydraulic laboratory not equaled by any now in existence anywhere in the world, in its scope both for ordinary small-scale researches and *for large-scale researches* in which flows of water up to 500 cubic feet per second could be measured with a degree of accuracy heretofore unequaled (viz, with errors of measurement not exceeding about one-tenth of 1 per cent), and many determinations made of hydraulic coefficients in formulas for measuring the flow of water so accurately that once made they would serve all practical needs for a hundred years to come.

Such large-scale experiments are highly important to American public service engineering, as a means of developing and testing improved forms of water-measurement weirs, for promoting better forms of baffle piers and other means of dissipating destructive energy of current at the foot of high over-fall dams and spillways, and as a means for devising better forms of sluiceways, more effective syphon spillways, and for developing standard economic methods of riprap for preventing the erosion of earthen river banks by swift currents.

Also, it was highly important, and was possible within this appropriation, to design this laboratory of such scale and scope as to permit much needed determinations of the *effect of turbulence* and of twisting currents upon measurements of the flow of water by weirs, current meters, Venturi meters, Pitot tubes, and other instruments, by means of experiments on such a large scale as to command the confidence of practical engineers to much greater degree than the small-scale determinations heretofore made.

But, as I have said above, this great opportunity has been sacrificed, apparently through lack of experience of the members of the Bureau staff to whom this problem of design was assigned, and who had no background of practical experience either in large engineering design, or in the special problems of design for controlling or measuring large volumes of water. *The problem of designing this laboratory was intrusted to skillful physicists rather than to experienced and skillful engineers.*

Substantially every one of the great hydraulic laboratories of Europe, which for 10 years past have been contributing so greatly to the advance of engineering knowledge, has been designed chiefly by an eminent engineer of mature age, *who had a background of 5 or 10 years or more of engineering experience on large and important work*, and so brought to his designing of the laboratory a highly valuable experience. Also it is worthy of note that the great contributions to the science and practice of hydraulics in America have been by engineers of large practical experience, like the late James B. Francis, Clemens Herschel, of Venturi Meter fame, and various other engineers, including those of the United States Reclamation Service, the hydrographic branch of the United States Geological Survey, and certain enterprising engineers of the United States Department of Agriculture, and other branches, and *not by mathematical physicists.*

Senator Ransdell will so well remember my many earnest conferences with him on these matters during the past eight years that he may wonder why I have been unable to successfully advise our friends of the Bureau toward making a better use of the appropriation. I must beg him to remember that the Director of the Bureau of Standards and his staff *have the sole authority over the design,* and that they naturally have pride of opinion in their own capacity and skill for meeting any conceivable requirement for scientific research. The laboratory will be more of a physicists' design than that of a design by engineers experienced in hydraulic construction.

In my more than a half century of engineering, largely on hydraulic problems of great magnitude, I have also happened to have an uncommonly large experience with problems of hydraulic experiment in various laboratories. For more than 20 years I have been deeply interested in hydraulic research, and have made three extended tours for study of the hydraulic laboratories of Europe and have personally visited most of the notable laboratories in America. The results of a part of these studies are set forth in the large volume which you possess, copies of which were given to a large number of your associates in Congress, entitled "Hydraulic Laboratory Practice." Also I have helped 10 or more American engineers to study in these laboratories abroad through the endowment of traveling scholarships each giving sufficient stipend for a year of study and travel abroad. Last summer, at my own expense, I made another tour of the European hydraulic laboratories, mainly for the purpose of learning of the very latest developments, and for aiding in the design of this national hydraulic laboratory at the Bureau of Standards.

I have tried in every reasonable way, as was stated in my letter to Senator Ransdell of June 24, 1930, to make my information available to the Bureau staff, but, although I have been treated with great politeness, I have been unable to bring them to understand the practical needs of various highly important features of the design.

In my letter of June 24, 1930, to Senator Ransdell, Secretary Lamont, and Director Burgess (which was published as Senate Document No. 208) I tried to make plain some of these matters. I am pleased to state that the later drawings for the laboratory by the Bureau staff, by whom four successive studies have been made by them, show vast improvement compared with their first sketches, which I mentioned in the communication just cited, and over which I was so greatly disturbed. But these Bureau designs still fall *far short of what might be possible in scope and precision* under this appropriation of $350,000, and after repeated conferences I am now on the point of making no further effort toward improving the design of this laboratory.

To show how hard I have tried to aid in making this national laboratory the very best in the world, I may state that in the preparation of various sets of drawings that I have presented to the Bureau staff, I have personally expended in pay rolls to assistant engineers and draftsmen, nearly $6,000, exclusive of office overhead and exclusive of my own time and traveling expenses, which time would have been of much value to me if otherwise applied.

I attach hereto a set of drawings and estimates of cost showing my latest and final effort, in a design which I am confident could be built within the appropriation and fit this laboratory both for the ordinary small-scale work, and for the large-scale fundamental research that is highly important to engineers in the Government services of reclamation, flood control, and river and harbor engineering, and also to engineers engaged in large problems of water supply and water power development. The attached estimates of cost were made up with extreme care in conference with the chief estimator of The Turner Construction Co., which built two of the most recent large buildings at the Bureau of Standards, and *include allowance in the unit cost for contractor's profit.* The total, which is slightly less than the appropriation of $350,000 made by Congress, thus covers the price at which *one of the foremost building contractors in the United States is ready to bid for the completed building.* Mr. Turner states that probably the contracts *could be now placed at a smaller total cost than this estimate,* because of the present business depression and the desire of various large contractors to maintain their organizations together at sacrifice of ordinary rates of profit.

I attach also a copy of my letter dated February 20, 1931, transmitting these designs to Doctor Burgess, which may interest you and some of your associates in the Senate and House, who made this appropriation of $350,000 available.

Following the letter to Doctor Burgess is a comparison of my plans with the most recent Bureau plans, which comparison I presented to him along with these final designs.

If the laboratory fails in some important respects to produce the results promised in the various congressional hearings, I hope that the documents which I now present will nevertheless permit you to still think kindly of my own efforts and good intentions. It may be well to explain that some of the features which are of highest importance, like the large measuring basin, the large forebay, the pump seats, and the main flumes, *have to be built into the very foundations of the original structure* and can not be properly added later. The pumps for producing the largest rates of discharge can advantageously be added a year or more later after previous research upon small model pumps for the purpose of perfecting the final design and so making of these large pumps instruments of research, useful for future designs in large drainage works.

Very truly yours,

JOHN R. FREEMAN.

[Copy]

FEBRUARY 21, 1931.

Dr. GEORGE K. BURGESS,
Director Bureau of Standards,
Washington, D. C.

DEAR DOCTOR BURGESS: I am extremely sorry to have been prevented by illness from attending the conference with you which I had intended to have on January 27. I had my Pullman space and transportation all engaged Monday, but ventured a visit to my doctor, who sent me to bed for two weeks of intensive rest cure. The reason I missed my conference with you in New York, at the American Society of Civil Engineers, on January 21, was that after listening to your paper and two or three others, I found myself "all in," and went back to my hotel and to bed, in order to recuperate for the evening ordeal, in which I was on the schedule for a conspicuous part.

This detention by illness, the longest that I have suffered in 50 years, upset my plans seriously, and, although I have been at the office for several days past, am not yet back to 100 per cent efficiency.

I now intend coming to Washington some time next week, for I still have hopes of making plain to you that the laboratory as proposed by Mr. Eaton *can not possibly fulfill the promises made to Congress about fundamental research.* The chief defect of the Bureau's design is the small size of its measuring basin, which will prevent making important research with fairly large discharges *on a cubic-foot basis* of direct measurement and with a precision close to one-tenth of 1 per cent.

Mr. Eaton has been relying largely on the Venturi meters, for basic measurements, but this will not command the confidence of those who know the possibility of error in Venturi measurements due to air bubbles, twisting of the current, and lack of precision in piezometer readings, particularly with relatively small quantities flowing.

An important defect in nearly all the European laboratories, except that at Obernach, including the costly new laboratory at Zurich, is this inability to *positively* measure large quantities *with precision.* Moreover, I hoped that our American laboratory might excel all now in existence in Europe and in America by its ability to make much needed fundamental research on weirs, dams, orifices, and channel flow, *with large quantities and a precision of measurement never yet equalled.*

My designs are worked out with this feature in view and with the idea of *fully meeting the promises made in the hearings before Congress.*

I regret that somehow in examining my designs your attention became chiefly focused on the large discharge proposed of 500 cubic feet per second instead of on the far more important feature of precise measurement of large quantities *in a measuring basin* with the aid of a quick moving diverting gate, which I am sure is entirely feasible from having used one in smaller-scale research. The quickly moving chronograph gate and the big measuring basin are fundamental requirements which have to be built into the original structure and its foundations. The pump for very large quantities can preferably be added later, after we have had some researches with model pumps, similar to the two set-ups that I saw in Europe last summer, one at Munich and another at Toulouse.

You may wonder at my earnestness in all of this, but I have been working on these ideas for more than 25 years and believe that now or never is the chance for a national hydraulic laboratory which can do things beyond the research of the many college laboratories and most of those in Europe, but which also can do the ordinary run of researches, which occupy most of the time of existing laboratories, with facilities not now excelled anywhere on earth.

The most eminent laboratory directors, like De Thierry, Rehbock, and Thoma have repeatedly urged on my attention that for the best routine work the laboratory should have abundant open floor space on which *temporary* set-ups of apparatus designed to meet the special problem can be conveniently erected and removed after the research is completed. In addition to the big flume, the big measuring basin, for facilities for precise measurement of large discharge, I have provided for both the small scale and the large scale research.

While at home ill I gave much thought to these matters and immediately upon returning to my office started Mr. Chick, at revising the drawings, so as to incorporate several improvements which both increased the capacity and lessened the cost, and I am now sending to you blue prints of this my final design marked "Study No. 4."

Many of the component parts, skimmer weir, diverting gate, forebay and forebay gate, also the special reinforcement of concrete will have the same details as shown in my previous set of about 27 sheets of blue prints.

Costs: On the basis of the unit costs in the Turner estimate, and while providing the same quality of construction shown in my latest previous design, including superabundant steel reinforcement of the concrete against temperature stresses and other stresses, and for preserving alignment and preventing distortion and settlement cracks, Mr. Chick, after carefully and precisely computing quantities, estimates a cost of buildings and fixed equipment, including contractor's profit at $289,480. Substantially the same items were previously estimated at $306,303, showing a saving of about $16,823 by simplification of design as per photostat of detailed estimate inclosed.

We find also that everything needed in portable apparatus to put the laboratory into immediate operative condition for four or five researches of the ordinary type going on simultaneously can be provided for the further sum of $59,812. *This brings the total cost slightly within the congressional appropriation of $350,000.*

Limestone finish: The preceding figures coming very closely to $350,000 for my design do not include limestone finish. We judge after allowing for the extent of the basement walls which are covered by a banking up of earth to avoid temperature stresses and also to give support, that a suitable amount of limestone trim, including parapet, window sills, and water-table course at the bottom, should not add more than $5,000, after deducting $4,150, which we have allowed for special concrete coloring and including window sills, window caps, etc. This extra $5,000 will be covered by the contingencies provided for in the following paragraphs.

For contingencies: As a safeguard for contingencies there can be held in reserve the cost of the propeller pump of 250 or 300 cubic feet per second discharge capacity, amounting to $12,000, which pump can be advantageously deferred for a year, pending research on a small model of same.

Moreover, parts of portable equipment, self-contained apparatus. etc., can be added gradually as cause for research develops, amounting to a total of about $15,000, which can, as you once suggested to me, be paid for from the first six months' appropriation for maintenance and operation. This gives a margin for contingencies of about $27,000, although I believe these contingencies will probably not arise.

Foundations.—I still maintain (and I am no novice in difficult foundations—for example, the Panama locks at Gatun, the dam site of rock broken by intersecting fault zones at Holter, Mont.; the dam site on possibly yielding foundations at San Pablo, Calif., etc., and from all that I have yet been able to learn about the underground conditions at the laboratory site, and from conferences with Doctor Stratton about foundations for your existing buildings) I believe the laboratory can be made safer against settlement cracks and distortion by practically floating the whole mass of the heavily reinforced foundation walls upon the decomposed rock on the levels which I have shown, than can be done by carrying detached foundation piers down to the so-called solid rock, which is not at all solid.

I am so confident that the whole laboratory could be completed *according to my designs herewith submitted*, with pumps upward of 250 cubic feet per second capacity, with attachments planned for future large pumps giving a total discharge capacity of 500 or perhaps 600 cubic feet per second, that I would be entirely willing to personally deposit the sum of $50,000 with the National Research Council, or other appropriate place, from which could be taken any sum found necessary to cover the over run or any sum necessary for repairs due to settlement cracks which occur within the next two years. I should make this deposit with the utmost confidence that it would not be called on for a single dollar, either for overrun or for repairs. Should loss occur I would take it cheerfully. It would simply be deducted from further contribution which I have been long intending to make for the advancement of hydraulic science.

I regret that in my personal conferences I have failed to make clear the purposes of design, and regret exceedingly that so much attention was given to the figure of 500 cubic feet per second of pump capacity, because this matter of *pump capacity is of no significance whatever in comparison with the necessity for a large measuring basin of substantially the size that I have indicated, fitted with a quick swinging gate, so that the error of measurement may rarely, if ever, greatly exceed one-tenth of 1 per cent.*

American services of water supply, flood control, and power development greatly need some precise, *large-scale* researches relative to flood discharge over dams, also discharges through orifices, and the determination of coefficients for new forms of water-measuring weirs and for determining coefficients of discharge of existing dams used for gaging flood discharge. Researches are needed for gate designs giving the least loss of head, also in baffle piers attached to the downstream face of dams for dissipating energy and preventing erosion, as well as for the effect of disturbance and turbulence in causing errors in measurement of discharge. I have provided for all of these in my designs.

The precision of measurement of large quantities (up to even 500 cubic feet per second) is the very essence of my design, and of its purpose to permit new determinations of weir coefficients and new forms of weir that should have world-wide acceptance for a century to come, and immediately be *of great practical value to hydraulic engineers engaged on large projects.*

The opportunity for fundamental research of this scope and quality of research would immediately stamp this laboratory as without a superior or equal in the world, and in my judgment, such fundamental research is of far greater importance to the greater Federal services than the mere ability to duplicate the *small-scale researches such as are within the capacity of many existing laboratories.*

Attached hereto are photostats of detailed estimates of cost, referred to above.

Since the inclosed sheets of blue prints include no elevations, it may be well to make plain that the estimates attached hereto comprise

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pediment, bridge, grading, and ornamental architectural accessories included in my previous estimates.

I inclose several sheets of comparisons of capacity, etc., which clearly demonstrate the superiority of the Freeman design, particularly considering that its cost will be no greater than that the Bureau design of February 4, 1931. Probably it will be much less.

Very truly yours,

JOHN R. FREEMAN.

APPENDIX NO. 1

Estimate of quantities and cost for constructing national hydraulic laboratory at Bureau of Standards, Washington, D. C.

[Estimate by A. C. Chick, based upon revised plans by John R. Freeman, as of February 14, 1931, and unit prices mostly submitted by Turner Construction Co., of Philadelphia, as of December 31, 1930. This estimate of quantities has been determined independently of that of December 31, 1930]

Item	Quantity	Unit	Unit cost	Estimated total cost
General contractor				
1. Concrete (liberal estimate; walls made exceptionally thick to prevent serious deflection and to aid in securing water-tightness).	176, 803	Cubic foot	$0. 251	$44, 378. 00
2. Reinforcement steel (reinforcement computed to take load stresses on basis of 16,000 pounds per square inch; ratio of steel to concrete, for resisting shrinkage and temperature stresses, has in all cases been taken at or greater than 0.005 volumetric basis, in walls, in excess of that required to take load stresses, with provision for contraction joints not over 50 feet apart).	629, 137	Pounds	. 330	20, 762. 00
3. Floor finish (dusted on)	55, 387	Square foot	. 050	2, 769. 00
4. Forms:				
Wood—				
(a) Footings	610	do	. 120	73. 00
(b) Floor slabs	6, 434	do	. 283	1, 820. 00
(c) Floors on steel	56, 866	do	. 145	8, 246. 00
(d) Walls (double)	31, 564	do	. 365	11, 520. 00
(e) Walls (curved)	1, 659	do	. 600	995. 00
(f) Stairs	365	Linear foot	1. 000	365. 00
(g) Sills and coping	1, 763	do	. 600	1, 057. 00
(h) Water table and belt	1, 784	do	1. 000	1, 784. 00
Metal—(a) Interior walls of main and return flumes	12, 370	Square foot	. 500	6, 185. 00
. Integral waterproofing: None provided. Allowance has been made for using a higher grade of concrete with extra quantity of cement, which is deemed a better guarantee of water-tighness than the use of integral waterproofing compounds.				
6. Special coloring of concrete trim to match Indiana limestone used on some of the other buildings at the Bureau of Standards. This includes special selection of aggregate.				1, 000. 00
7. Exterior finish of concrete wall surfaces (including rustication).	5, 130	Square foot	. 060	309. 00
8. Interior concrete finish (pointing walls and ceilings)	126, 210	do	. 020	2, 524. 00
9. Interior finish of main and return flumes (pointed, carborundum rubbed, and smoothly surfaced).	12, 370	do	. 060	742. 00
10. Brickwork:				
Facebrick	132	Thousand	70. 000	9, 240. 00
Common brick	188	do	42. 000	7, 896. 00
Basement floor	21	do	40. 000	840. 00
11. Scaffold lumber	50	Thousand feet	30. 000	1, 500. 00
12. Wood doors	918	Square foot	1. 750	1, 606. 00
13. Roof plank (2-inch)	2, 200	do	. 160	352. 00
14. Bridge and walkway (main entrance, 2d floor)	380	do	1. 500	570. 00
15. Leveling	25, 000	do	. 020	500. 00
16. Hardware				450. 00
17. Contraction joints in concrete walls (copper)	628	Linear foot	1. 000	628. 00
Subtotal (general contractor)				128, 111. 00

Estimate of quantities and cost for constructing national hydraulic laboratory at Bureau of Standards, Washington, D. C.—Continued

Item	Quantity	Unit	Unit cost	Estimated total cost
Subcontractor				
18. Clearing site				$500.00
19. Excavation	27,700	Cubic yards	$0.850	23,545.00
20. Backfill and rough grading				1,000.00
21. Metal column forms (rented)	39		15.000	585.00
22. Structural steel, including paint	322	Ton	70.000	22,540.00
23. Structural steel (beams and plate) for propeller pump chamber.	50	do	100.000	5,000.00
24. Structural steel—forebay	85	do	100.000	8,500.00
25. Structural steel in tie across outlet of forebay, including vertical girders, anchor rods, steel plate lining for water passages, etc.	46	do	100.000	4,600.00
26. Steel stairs	1,035	Square foot	2.250	2,328.00
27. Iron-pipe rail, 1¼-inch	577	Linear foot	1.800	1,038.00
28. Iron ladders	50	Pound	.100	5.00
29. Steel commercial projected sash	10,260	Square foot	.450	4,617.00
30. Metal toilet partitions	8		50.000	400.00
31. Wood and glass partitions	2,200	Square foot	.800	1,760.00
32. Toilet walls (8-inch brick)	18.5	Thousand	42.000	777.00
33. Plastering (Defer).				
34. Roofing (tar and gravel, 20-year)	23,550	Square foot	.110	2,590.00
35. Flashing	900	Linear foot	.350	315.00
36. Painting (wood and iron only)	39,700	Square foot	.050	1,985
37. Glazing	10,260	do	.200	2,052.00
38. Plumbing (fixtures in place only)	29	Fixtures	100.000	2,900.00
39. Hot and cold water (piping and hot water supply)				720.00
40. Ground-water tile drains	1,200	Linear foot	.400	480.00
41. Cast-iron drains:				
(*a*) Inside building—				
8-inch	70	do	1.000	70.00
6-inch	350	do	.900	315.00
4-inch	70	do	.700	49.00
(*b*) Outside building—				
8-inch	35	do	1.000	35.00
6-inch	135	do	.900	121.00
42. Tile drain pipe:				
12-inch to sewer in Tilden Street	50	do	2.000	100.00
8-inch	100	do	.400	40.00
6-inch	400	do	.300	120.00
43. Manhole catch basin				75.00
44. Valves on cast-iron drains:				
8-inch gate	1			45.00
6-inch gate	1			35.00
45. Floor drains with traps and strainer covers:				
8-inch	2			125.00
6-inch	1			50.00
4-inch	1			20.00
46. Heating (radiation surface and piping only: Supply from central heating plant).	10,420	Square foot	1,250	13,025.00
47. Electric wiring (lighting and convenience outlets only):				
Lighting	310	Outlet	12.000	3,720.00
Convenience outlet	50	do	5.000	250.00
48. Steam and electric lines from power house				10,000.00
49. Water and gas connections:				
Water				1,250.00
6-inch water meter				350.00
Two 8-inch valves				90.00
Gas connection				200.00
50. Crane and rails (two only at present)				2,800.00
51. Elevator (shaft only provided).				
52. Projected pediments for outside trim				1,000.00
53. Borings (already made)				500.00
54. Propeller pump discharge pipe (riveted steel)	4.5	Ton	90.000	405.00
Subtotal (subcontractor)				123,017.00

Estimate of quantities and cost for constructing national hydraulic laboratory at Bureau of Standards, Washington, D. C.—Continued

SUMMARY

Item	Quantity	Unit	Unit cost	Estimated total cost
General contractor				$128, 111. 00
1½ per cent tools and supplies				1, 920. 00
Cleaning	63, 300	Square foot	$0. 0300	1, 899. 00
2 per cent liability insurance				2, 560. 00
5 per cent general expense				6, 400. 00
Special protection	63, 300	do	. 0025	158. 00
				141, 048. 00
Subcontractor				123, 017. 00
Engineering department				2, 500. 00
Construction department	4	Month		2, 800. 00
Accounting department	4	do		2, 800. 00
Installation				3, 000. 00
Plant rental—				
Concrete	6, 550	Cubic yards	. 4000	2, 620. 00
Brick	340	Thousand	. 5000	170. 00
				136, 907. 00

General contractor	$141, 048
Subcontractor	136, 907
Contractor's bond (1⅛ per cent of $277,955)	3, 125
Architect's fee	8, 400
Grand total for building and fixed apparatus	289, 480

The above estimate of $289,480 covers everything in the line of building and foundations and fixed equipment needed for greatly expanding the scale of experimentation as to discharges of from 500 to 600 cubic feet per second as proposed in the hearings before Congress; also, for researches on scale effect, etc., and fundamental research to meet practical requirements for many years to come.

It includes *a large supply basin*, a large forebay, *a large experiment flume*, and *a large measuring basin* sufficient for all future needs of this laboratory, which for economy and efficiency *must be incorporated in the foundations of the original structure*

In addition, it provides abundant clear floor space for research work by means of a wide variety of temporary set-ups, using volumes of water seldom exceeding 5 to 10 cubic feet per second, but permitting the use of quantities up to or greater than 100 cubic feet per second, for this purpose, if desired.

Provision is made for installation now, or at any future time, of a large propeller-type pump, so arranged as to permit fundamental research on cavitation and turbulence, in the pump itself, as well as supplying the need of a large quantity (250 to 300 cubic feet per second) of water for miscellaneous research work in the large flume, or in the return flume, or in apparatus temporarily set up in either of said flumes, the floors of which provide a substantial support for very heavy floor loads.

Estimate of cost of semifixed equipment and apparatus necessary to make the national hydraulic laboratory operative upon completion of the building.

None of the following items have been included in the above estimate, which purports to cover only the building, foundations, and fixed equipment.

1. Skimmer weir for 40-foot diameter steel forebay. The final design should preferably be based on experiments made on a small scale model of one-eighth to one-fourth full-size linear dimensions. Present designs (Dec. 30, 1930) show that this skimmer weir and down spout, with necessary counterbalancing water tanks for compensating excesssive buoyancy, will weigh approximately 20.5 tons. A small, local structural steel company has submitted a bid of $5,500 for supplying this skimmer weir, complete; to this should be added, say, $500 for installation, making its total cost, in place $6, 000
2. Hoisting tackle for skimmer weir; 30-ton capacity, endless, screw-drum winch, with 6-part wire-rope hoist 1, 000

3. Glass panels in main flume and return flume	$2, 000
4. Stilling plates (included in cost of steel forebay).	
5. Pivot-knife gate at discharge end of main flume—hand operated at first for small quantities of water; equipment for compressed-air operation for large quantities can be installed at any desired future time at a cost probably not exceeding $1,500	1, 500
6. Venturi meter 6 by 3 feet throat *Defer installation.* The intake and outlet sections should be installed now. These consist of steel plate sections embedded in concrete and flanged to permit future attachment of the Venturi meter—3 tons, at $120	360
7. Tilting river flume. Make flanged connection to steel forebay at this time and defer piping. One 4-foot diameter saddle and flange with cover plate is included in cost of piping.	
8. Miscellaneous small flumes:	
One glass-walled flume about 3 feet deep and 1.5 feet wide by about 50 feet long (demountable)	2, 000
Constant-head tank and weir box for above flume (portable)	1, 000
9. Miscellaneous small apparatus, gages, etc., over and above that already possessed by the Bureau of Standards	2, 000
10. Electrical equipment, transformers, etc., sufficient to provide lighting and furnish power to all small pumps	5, 000
11. Piping, valves, etc., necessary to make laboratory operative for fully 90 per cent of all contemplated work for the next two years	10, 000

12. Centrifugal pumps (motors and complete equipment):		
One 25 cubic foot per second, capacity	$3, 000	
One 20 cubic foot per second (for measuring basin)	2, 500	
One 10 cubic foot per second	1, 600	
Two 5 cubic foot per second	2, 600	
One 3 cubic foot per second	900	
One 2 cubic foot per second	700	
Plus installation and connection (25 per cent)	2, 800	
		14, 100
13. One 250 cubic foot per second adjustable-blade propeller pump (could be deferred a year or more) complete with motor thrust bearing, etc		12, 000
14. Additional hoisting equipment:		
For return flume, 2-ton block and trolley		150
For forebay gates, 2½-ton block and trolley		200
15. Wooden forebay gates and stop logs		500
16. Two portable constant-head tanks and weir boxes for miscellaneous research set-ups handling not more than 5 cubic foot-seconds		2, 000
Total		59, 810

SUMMARY OF TOTAL ESTIMATE OF COST OF BUILDING AND EQUIPMENT

Building and fixed equipment	$289, 480
Semifixed equipment and apparatus	59, 810
Total	349, 290

If necessary some savings could be made by deferring a part of the above equipment for a year as follows:

Propeller pump	$12, 000
Portable constant head tank	1, 000
25 cubic foot per second centrifugal pump	3, 000
Total savings thus possible	16, 000

Bringing total necessary cost of entire laboratory buildings and equipment ready for service to $233,290; thus leaving $16,710 to take care of any possible contingencies.

APPENDIX NO. 2 TO LETTER TO DR. GEORGE K. BURGESS, DIRECTOR

Comparison of essential features of J. R. Freeman's study No. 4, as of February 14, 1931, with the Bureau of Standards' design No. II, as modified up to February 4, 1931. (By John R. Freeman and A. C. Chick)

Item	J. R. Freeman's study No. 4, Feb. 14, 1931	Bureau of Standards' design No. II, Feb. 4, 1931
Size of building:		
Dimensions—		
Head (east) portion	103 feet 8 inches by 115 feet 8 inches	81 feet by 92 feet 6 inches, plus supply basin extension, 40 feet by 85 feet 6 inches.
Narrow (west) portion	62 feet by 201 feet 8 inches	61 feet by 203 feet 6 inches, plus measuring basin extension, 45 feet 6 inches by 62 feet.
Contents—		
Exclusive of measuring basin and supply basin	1,075,600 cubic feet	1,026,950 cubic feet.
Including measuring basin and supply basin	1,434,500 cubic feet	1,302,550 cubic feet.
Foundation area	24,500 square feet	26,150 square feet.
Superstructure area	24,500 square feet	19,920 square feet.
Foundation area that serves no useful purpose for superstructure	None	6,230 square feet.
Measuring basin: [1]		
Surface area	4,080 square feet	2,540 square feet.
Usable depth	20 feet	12 feet.
Capacity	81,600 cubic feet (Inside of building.)	30,480 cubic feet. (Outside of building.)
Forebay [2]	40-foot diameter; steel; 44 feet high above flume floor.	26 by 27 feet square; concrete; 25 feet high above flume floor.
Pump supply basin:		
Area	8,840 square feet	High level 4,935 square feet. Low level 5,000 square feet Total 9,935 square feet.
Usable water depth	14 to 16 feet	High level 9 feet. Low level 7 feet.±
Usable volume	124,000 to 140,000 cubic feet (Inside building.)	High level 44,400 cubic feet. Low level 35,000 cubic feet.± Total 79,400 cubic feet. (Partly outside building.)
Main flume;		
Cross-section [3]—		
Width	15 feet	12 feet.
Maximum depth	21 feet	Do.
Normal depth	16 feet	Do.
Usable length	222 feet	213 feet.

Return flume: [4]		
Cross-section—		
Width	8 feet	6 feet.
Depth	11 feet	13 feet.
Usable length	190 feet	168 feet.
High level return flume [5]	None; 36-inch pipe used instead as more economical of space and more convenient.	6 feet wide by 13 feet deep. (Not needed.)
Permanent Venturi meters [6]	None; or can be one 6 by 3 feet with capacity of 175 cubic feet per second; or one 8 by 4 feet, with capacity of 300 cubic feet per second.	Two; One 8 by 4 feet, with capacity of 300 cubic feet per second. One 3 by 1m feet, with capacity of 45 cubic feet per second.
Auxiliary second floor [7]	Feasible and inexpensive	None.[8]
Third floor	None	Useful area: Single area 45 by 78 feet unobstructed.
Roof	Concrete [9]	Poured gypsum on sheet rock.[10]
Gates	3 timber gates [12]	7 metal gates.[13]
Skimmer weir	Single unit [14]	4 units.[15]
Length of overflow crest	2,200 linear feet	1,600 linear feet.
Water-supply line for miscellaneous set ups	30-inch diameter [16]	30 and 20-inch.[17] (Single pipe line.)
Weigh tanks	None in beginning [18]	2 tanks, each of 20 tons, or about 640 cubic feet, capacity.
Basement story	18 feet clear height [19]	14 feet clear height.
Total floor area	3, 940 square feet	6,125 square feet.
Useful clear area	2,800 square feet	3, 330 square feet.

[1] Measuring basin of Bureau design is entirely outside the building proper. It must therefore be covered with a roof (or floor) which will serve no other useful purpose. No portion of the north, south, or west walls of the Bureau design for measuring basin is so located as to serve as foundation walls of the proposed future extension of the laboratory in that direction. The proposed future enlarging of the Bureau measuring basin is not a feasible thing to do, because of extreme difficulty of making new concrete joints water-tight where new walls and floor join the old structure.

[2] Bureau's concrete forebay is subject to serious cracking and consequent leakage. It is more expensive to construct than the steel cylinder. It also is not as adaptable as the circular steel forebay to the many demands for attaching pipes for supplying water to experimental set-ups or for attaching pump discharge pipes.

[3] The purpose of the large cross-section of the Freeman flume is to give convenient space and "elbow room" for fundamental research on large depths on many forms of weirs, dams, baffle piers, and Venturi meters, under both normal and disturbed or turbulent flow.

[4] The greater depth of the Bureau return flume makes the use of this flume for experimental purposes more difficult and inaccessible.

[5] The Bureau's high-level return flume is a needless expense. It's primary purpose is to return water to the supply basin from small experiments using not over 40 or 50 cubic feet per second. A pipe line 36 inches in diameter would serve equally well. The inclusion of this high-level return flume in the Bureau design requires that this portion of the laboratory building be about 8 feet wider than would otherwise be necessary. The space thus involved above the first floor (8 feet wide by 31 feet high by 203 feet long) (50,400 cubic feet and costing probably upward of $5,000) is of little, if any, practical use.

[6] For water measurement purposes this is less accurate and precise over a wider range than the measuring basin or special forms of weir.

[7] The second floor in J. R. Freeman's study No. 4 for the entire length of the narrow portion of the building and north of the central building columns, can be inexpensively extended to the south edge of the main flume wherever desired, for increased width (as for a crooked river flume) supported on steel columns 20 feet apart, so arranged as not to interfere materially with the operation of the main flume. Bracket supports can be provided on the columns along the north side of the building so that, to any extent desired, second floor area over the main flume can be extended by removable flooring.

[8] Extension of second floor to south edge of main flume has been considered.

[9] Useful for floor load of 50 pounds per square foot over entire area and is available for experiments on roof.

[10] Not durable and not strong; can not be used for out-of-door experiments on roof.

[12] Timber gates are much more practical, durable, and cheap; more convenient for attachments. Similar timber gates are in almost universal use for 50 years past in the large water-power developments in New England. Mr. Freeman has designed many, such timber gates which have been long in successful use.

[13] Expensive and cumbrous.

[14] Less costly; more readily and easily adjusted with precision.

[15] Cumbrous; difficult of precise adjustment.

[16] Serves 2 floors.

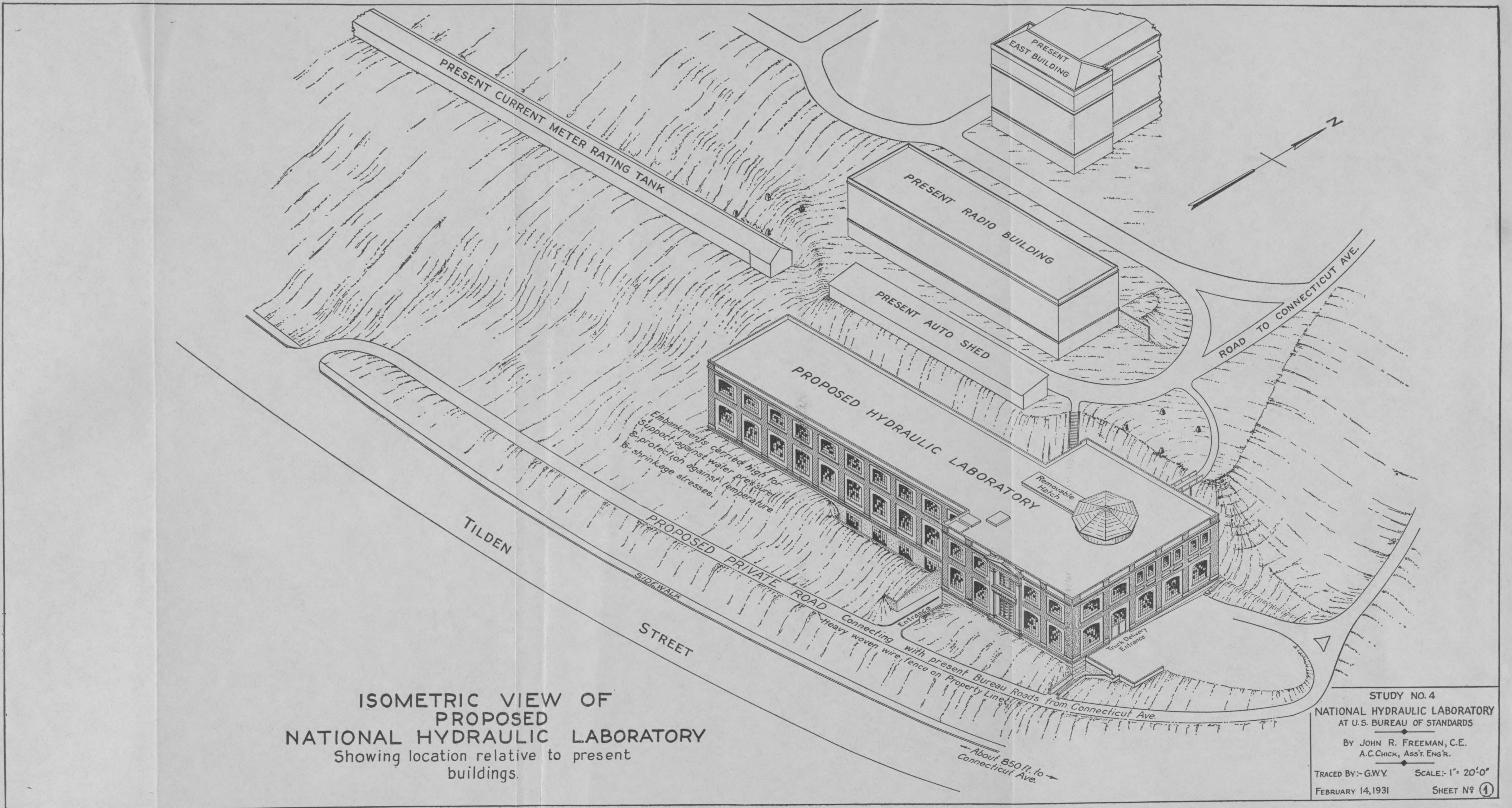
[17] Serves 1 floor.

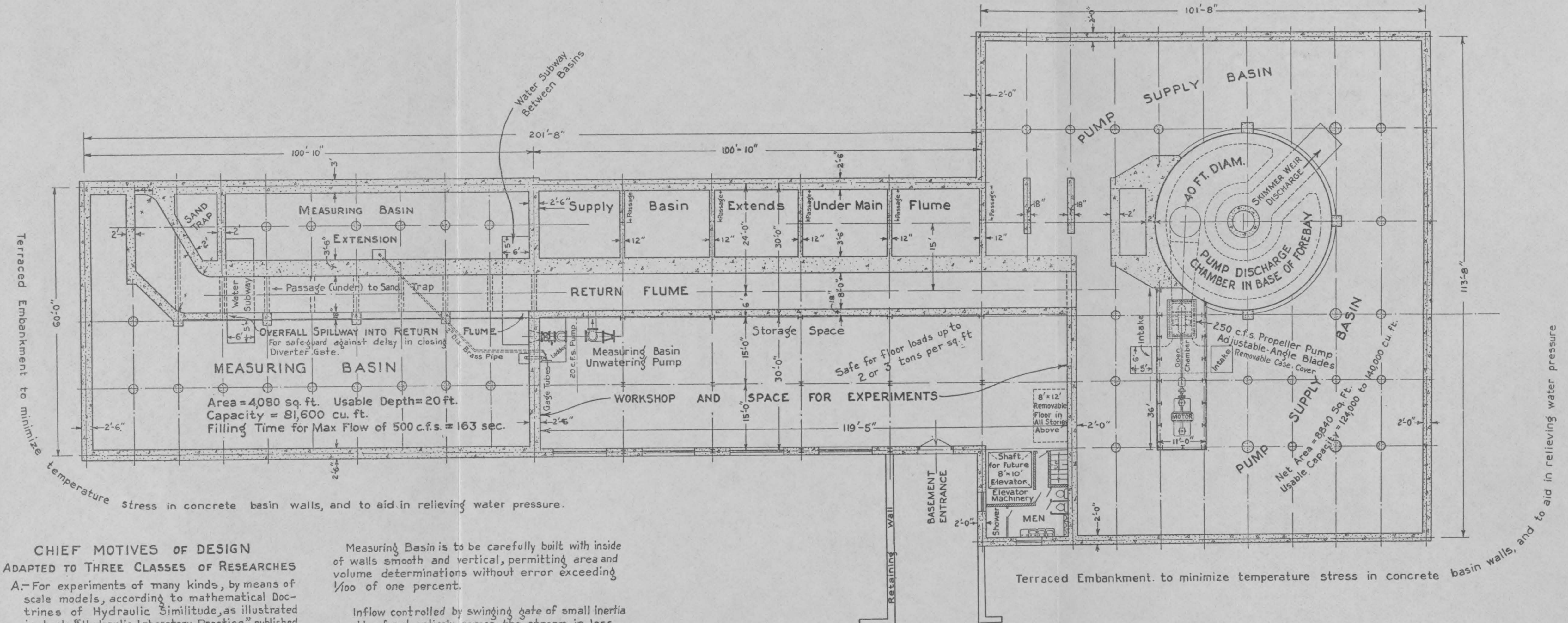
[18] Space is provided for adding these tanks in future if desired.

[19] Great height desirable for photographic records.

Comparison of essential features of J. R. Freeman's study No. 4, as of February 14, 1931, with the Bureau of Standards' design No. II, as modified up to February 4, 1931—Continued

Item	J. R. Freeman's study No. 4, Feb. 14, 1931	Bureau of Standards' design No. II, Feb. 4, 1931
First story (clear height)	18 feet [19]	16 feet.
Total area (within walls)	23,700 square feet	18,870 square feet.
Floor area, exclusive of forebay, main flume, and open-top return flume	15,900 square feet	13,000 square feet.
Space used for offices, elevator, and stairs	240 square feet	1,250 square feet.
Useful clear floor space for experiment purposes	12,100 square feet	9,250 square feet.
Second story (clear height)	14.5 feet	14.5 feet.
Total area (within building walls)	23,700 square feet	18,870 square feet.
Total floor area exclusive of forebay and high walls of main flume	16,550 square feet	11,720 square feet.
Total office space plus toilets, elevator, and stairways	2,410 square feet	1,240 square feet.
Useful clear floor space, for experiment purposes	13,300 square feet	8,360 square feet.
Third story (clear height)	None	11 feet.±
Total area (within building walls)		7,000 square feet.
Total area in office space, elevator, and stairway		1,240 square feet.
Useful clear floor space for experiment purposes		5,100 square feet.
Summary of useful clear floor space for experiment set-ups:		
Basement	2,800 square feet	3,330 square feet.
First story	12,100 square feet	9,250 square feet.
Second story	13,300 square feet	8,360 square feet.
Third story		5,100 square feet.
Total	28,200 square feet	26,040 square feet.
Foundations [20]	To sound undisturbed decomposed rock, like that for all present buildings at Bureau of Standards, except new power house.[21]	Carried much deeper to so-called "firm" rock.
Propeller pump	250 cubic feet per second; no suction lift [22]	None.
Centrifugal pumps:		
Large size [23]	200 cubic foot-seconds (future)	125 cubic foot-seconds (future?). 75 cubic foot-seconds (future?). 75 cubic foot-seconds. (Submerged.)
Small pumps—		
For unwatering measuring basin	20 cubic foot-seconds	20 cubic foot-seconds.
For supplying small experiments	25 cubic foot-seconds 10 cubic foot-seconds 5 cubic foot-seconds	20 cubic foot-seconds. 10 cubic foot-seconds. 5 cubic foot-seconds.
For supplying self-contained constant-head units	5 cubic foot-seconds 3 cubic foot-seconds 2 cubic foot-seconds	


PRESENT CURRENT METER RATING TANK
PRESENT EAST BUILDING
PRESENT RADIO BUILDING
PRESENT AUTO SHED
N
ROAD TO CONNECTICUT AVE.
PROPOSED HYDRAULIC LABORATORY
Removable Hatch
Embankments carried high for Support against water pressure & protection against temperature & shrinkage stresses.
TILDEN STREET
SIDEWALK
PROPOSED PRIVATE ROAD Connecting with present Bureau Roads from Connecticut Ave.
Heavy woven wire fence on Property Line
Entrance
Truck Delivery Entrance
About 850 ft. to Connecticut Ave.
ISOMETRIC VIEW OF PROPOSED NATIONAL HYDRAULIC LABORATORY
Showing location relative to present buildings.
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C.CHICK, ASS'T. ENG'R.
TRACED BY:- G.W.Y.
SCALE:- 1" = 20'-0"
FEBRUARY 14, 1931
SHEET Nº 1



PLAN OF BASEMENT

Scale: 1/8" = 1'-0"

CHIEF MOTIVES OF DESIGN

Adapted to Three Classes of Researches

A.– For experiments of many kinds, by means of scale models, according to mathematical Doctrines of Hydraulic Similitude, as illustrated in book "Hydraulic Laboratory Practice," published by Am. Soc. Mechanical Engineers, 1929.

B.– For Large Scale Fundamental Research for determining with great precision and accuracy Coefficients of Discharge of Dams, Weirs, "Venturis", Orifices, and Channels – of great variety of form, roughness of surface, and various disturbance of approaching currents, for practical use.

C.– "Scale Effect", or extent of difference in coefficients between large structures and small models, due surface tension, boundary layer effects, turbulence, etc.

Measuring Basin is to be carefully built with inside of walls smooth and vertical, permitting area and volume determinations without error exceeding 1/100 of one percent.

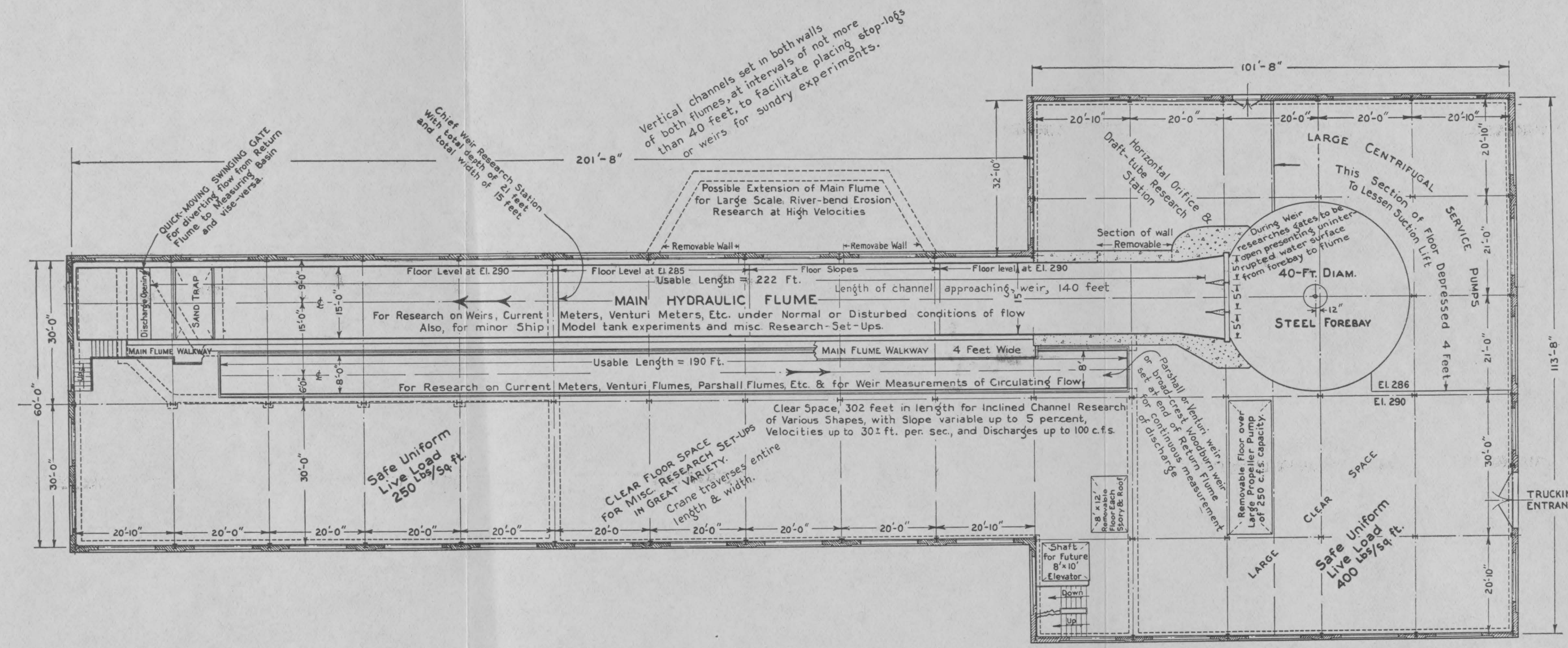
Inflow controlled by swinging gate of small inertia capable of put entirely across the stream in less than 1/2 second, and of mid-point being timed by chronograph within about 1/10 second, so that for all except largest quantities the precision of measurements of rate of discharge need contain no errors greater than 1/10 of one percent, and give coefficients with far greater accuracy than heretofore possible.

For Class "A" Researches, constituting probably 90 percent of all laboratory work, no such great precision of discharge measurement is necessary.

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T. ENG'R

TRACED BY:- E.C.A — SCALE:- 1/8" = 1'-0"
FEBRUARY 14, 1931 — SHEET No. 2



PLAN OF 1ST STORY
Scale:- 1/8" = 1'-0"

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R

TRACED BY:- E.C.A. SCALE:- 1/8" = 1'-0"
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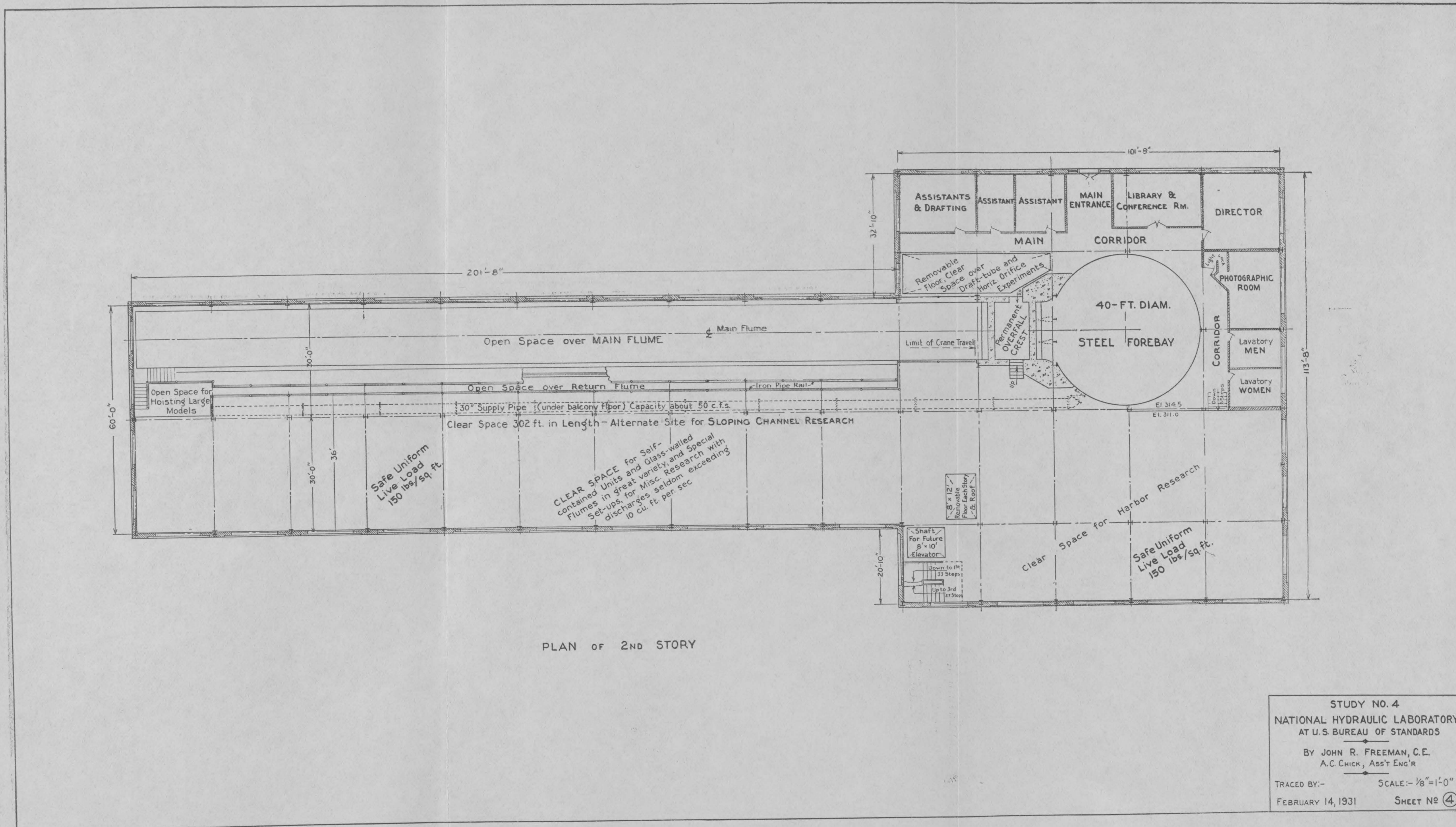
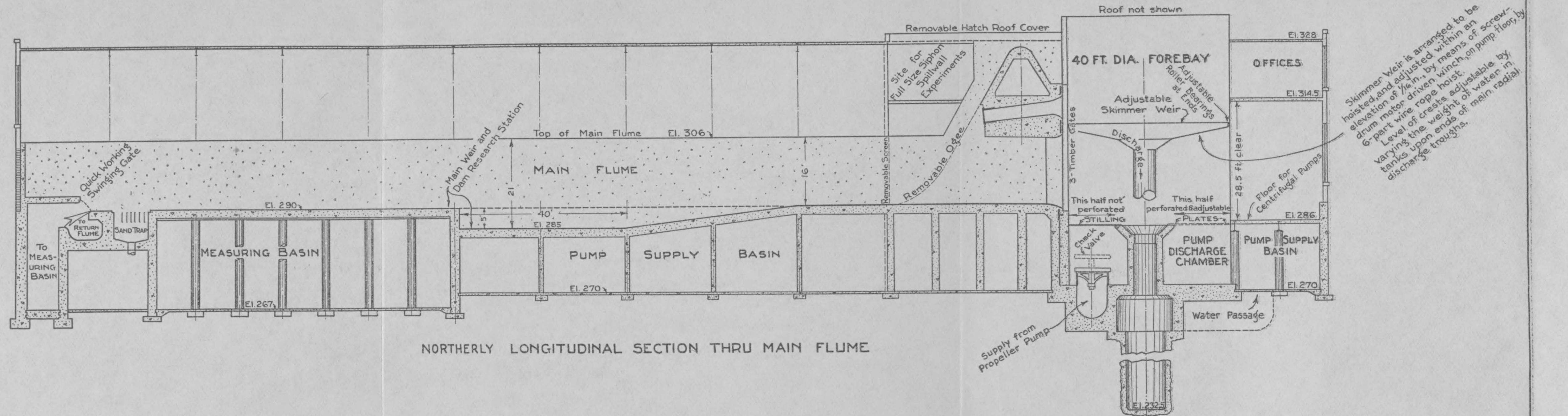
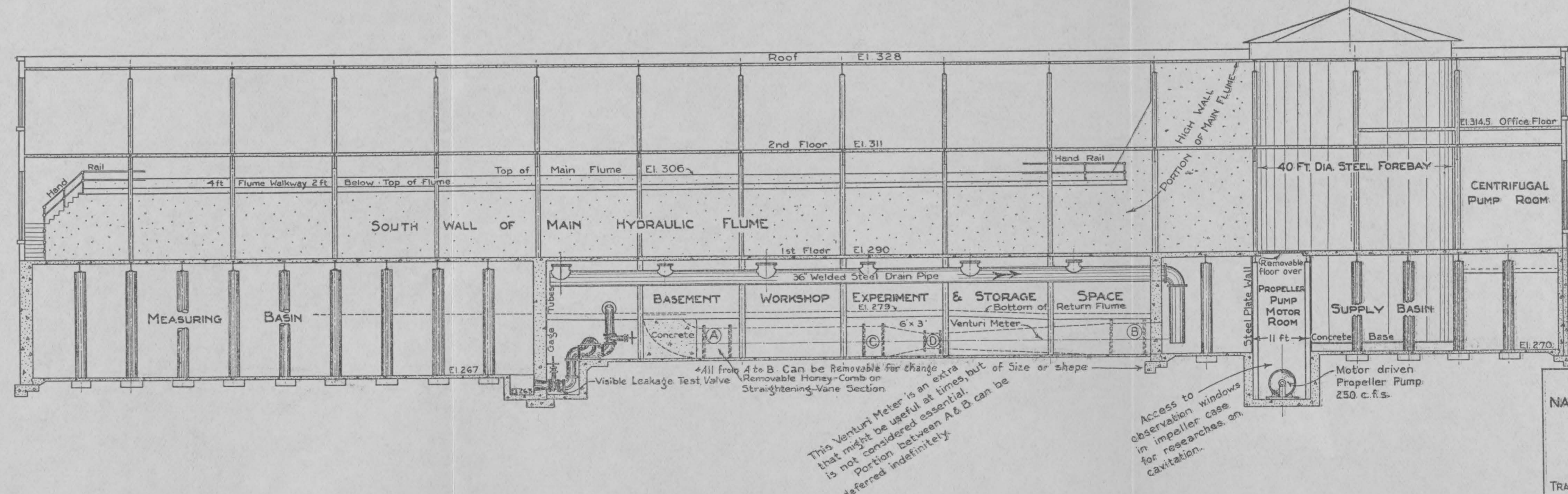


PLAN OF 2ND STORY



NORTHERLY LONGITUDINAL SECTION THRU MAIN FLUME



SOUTHERLY, LONGITUDINAL SECTION THRU WORK-SHOP

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T. ENG'R.

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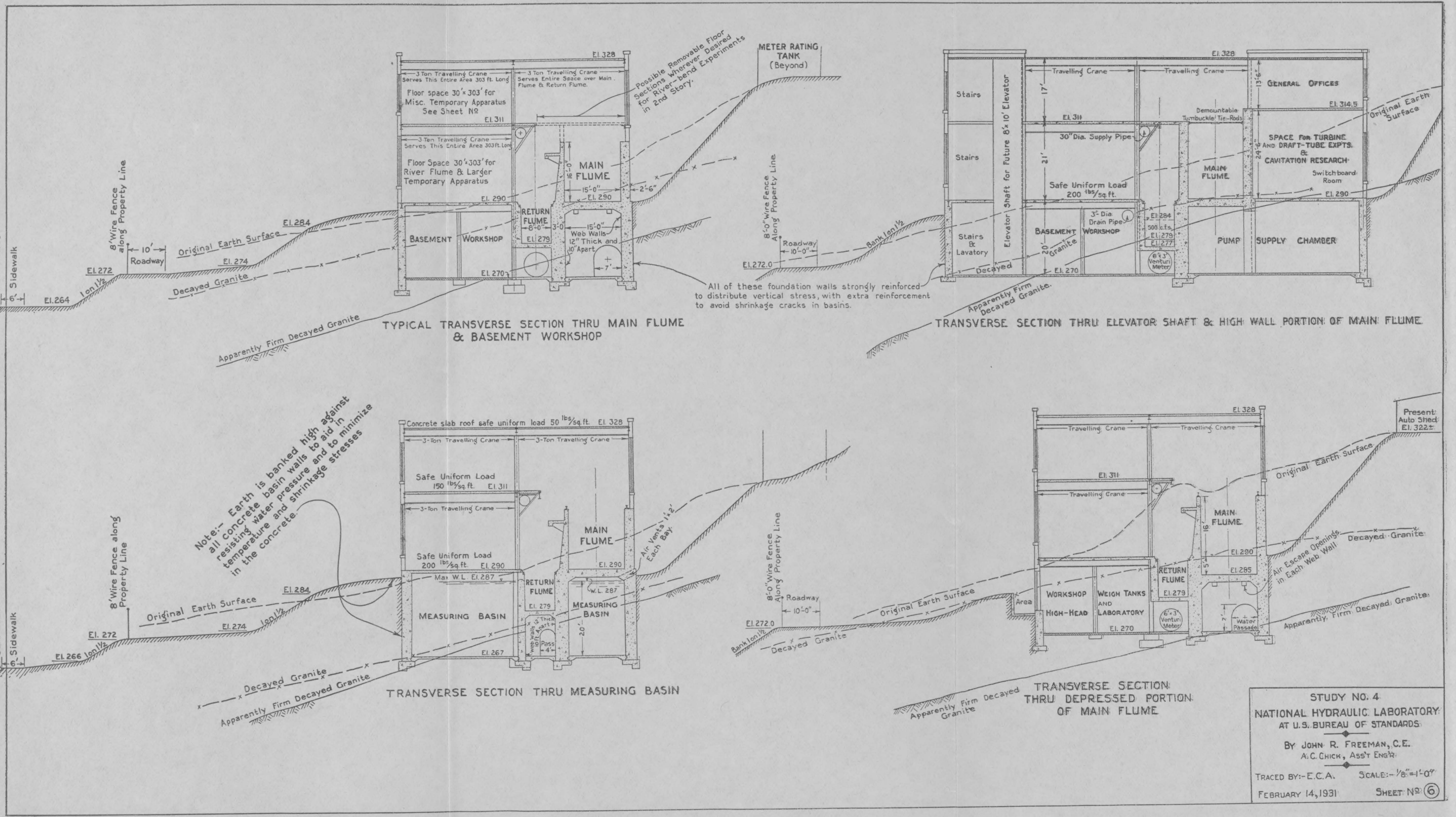
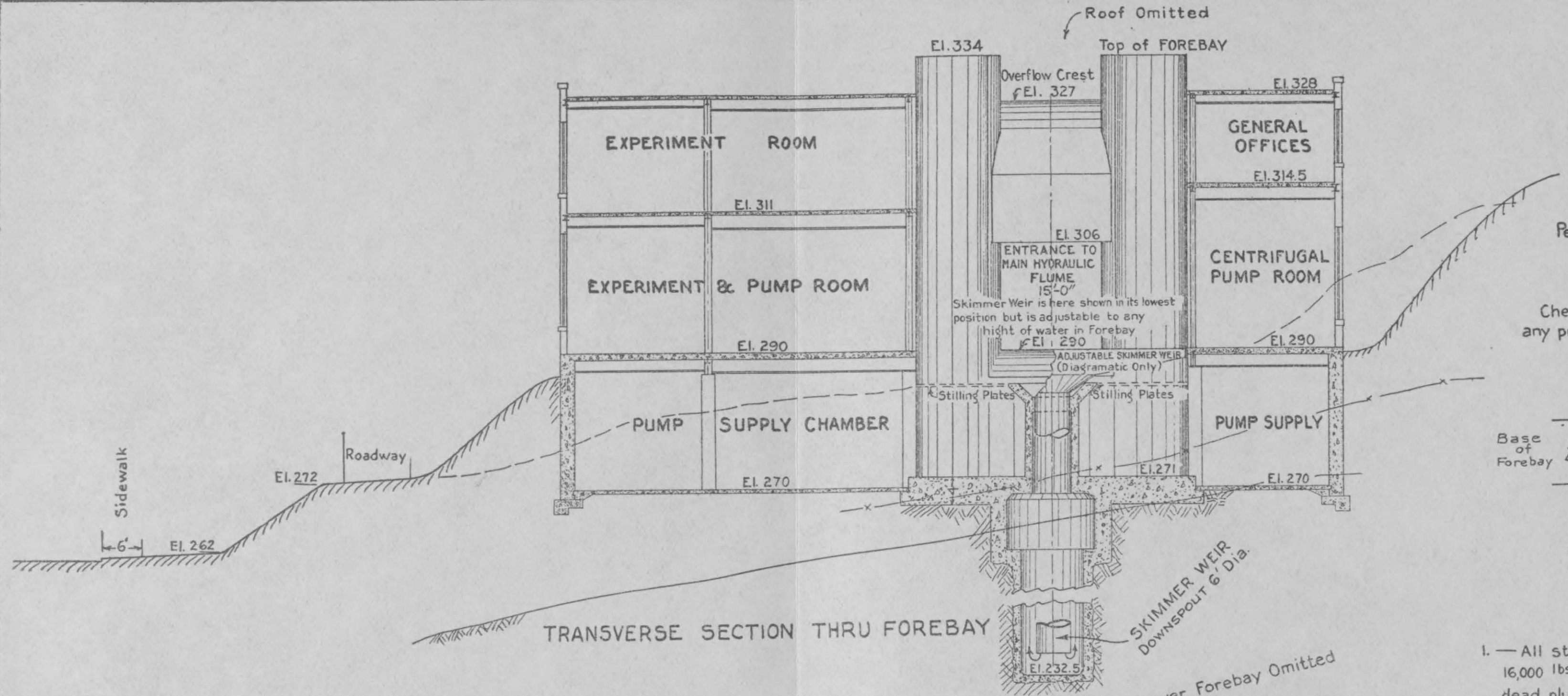
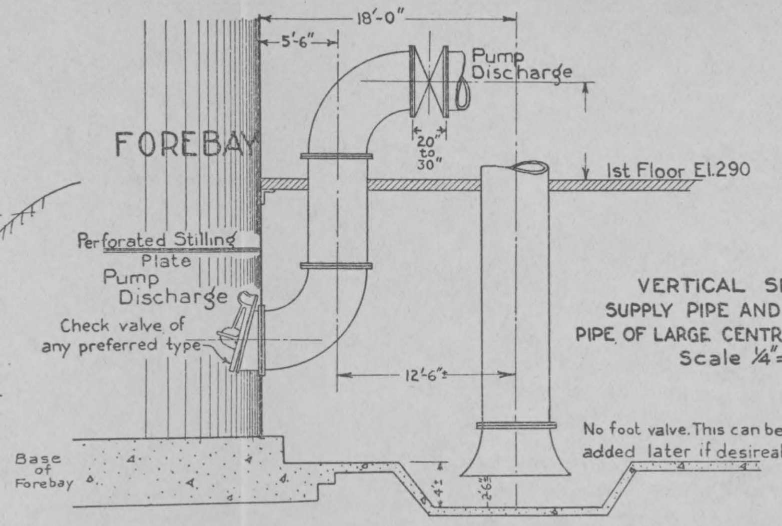
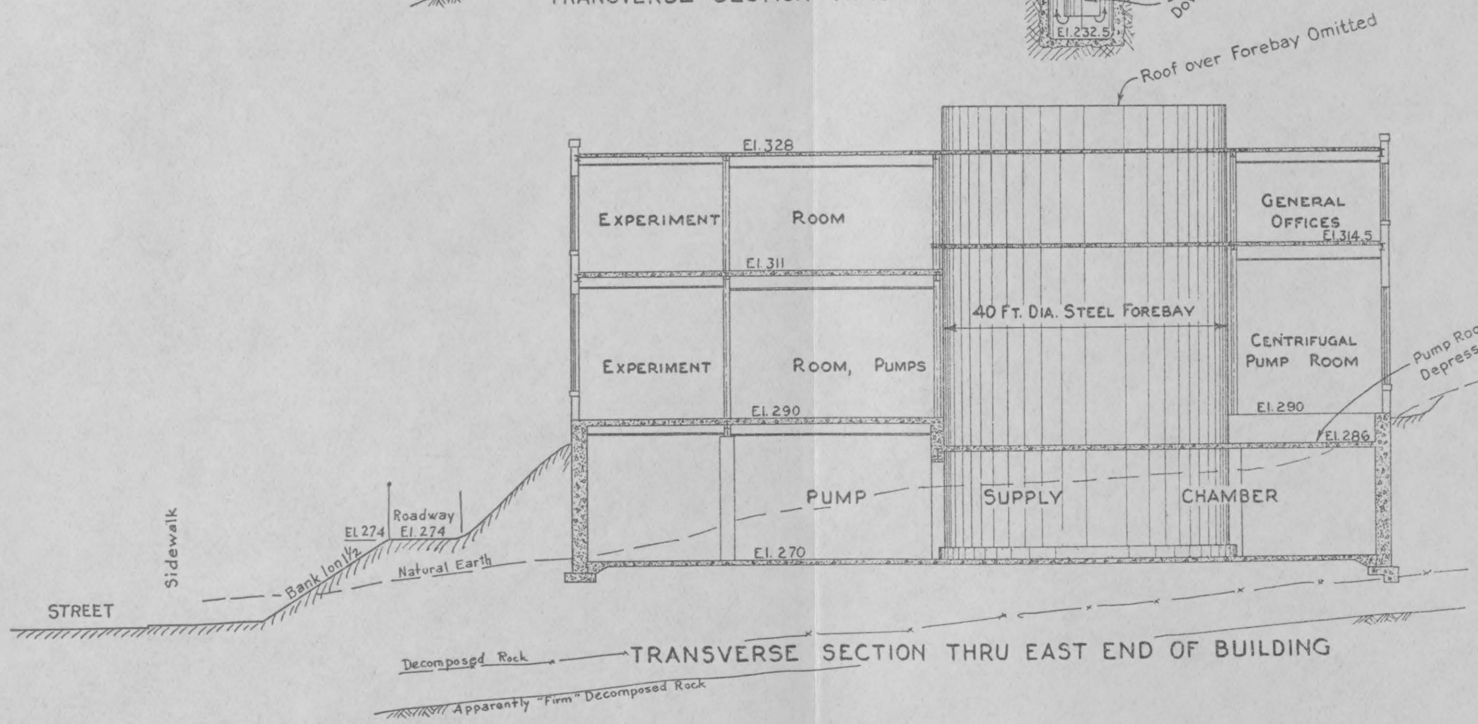

TYPICAL TRANSVERSE SECTION THRU MAIN FLUME & BASEMENT WORKSHOP
TRANSVERSE SECTION THRU ELEVATOR SHAFT & HIGH WALL PORTION OF MAIN FLUME
TRANSVERSE SECTION THRU MEASURING BASIN
TRANSVERSE SECTION THRU DEPRESSED PORTION OF MAIN FLUME
TILDEN STREET
Curb El. 263±
Curb El. 264±
Sidewalk
8' Wire Fence along Property Line
8'-0" Wire Fence Along Property Line
Roadway
Original Earth Surface
Decayed Granite
Apparently Firm Decayed Granite
METER RATING TANK (Beyond)
Possible Removable Floor Sections wherever Desired for River-bend Experiments in 2nd Story.
3-Ton Travelling Crane Serves This Entire Area 303 ft. Long
3-Ton Travelling Crane Serves Entire Space over Main Flume & Return Flume.
Floor space 30'×303' for Misc. Temporary Apparatus See Sheet No
Floor Space 30'×303' for River Flume & Larger Temporary Apparatus
MAIN FLUME
RETURN FLUME
BASEMENT WORKSHOP
Web Walls 12" Thick and 10' Apart
All of these foundation walls strongly reinforced to distribute vertical stress, with extra reinforcement to avoid shrinkage cracks in basins.
Stairs
Stairs & Lavatory
Elevator Shaft for Future 8'×10' Elevator
Travelling Crane
30" Dia. Supply Pipe
Safe Uniform Load 200 lbs/sq.ft.
3' Dia. Drain Pipe
6'×3' Venturi Meter
500 c.f.s.
Demountable Turnbuckle Tie-Rods
GENERAL OFFICES
SPACE FOR TURBINE AND DRAFT-TUBE EXPTS. & CAVITATION RESEARCH
Switchboard Room
PUMP SUPPLY CHAMBER
Concrete slab roof safe uniform load 50 lbs/sq.ft. El. 328
Safe Uniform Load 150 lbs/sq.ft.
Safe Uniform Load 200 lbs/sq.ft.
Max. W.L. El. 287
MEASURING BASIN
Air Vents 1×2' Each Bay
Note:- Earth is banked high against all concrete basin walls to aid in resisting water pressure and to minimize temperature and shrinkage stresses in the concrete.
Present Auto Shed El. 322±
Area
WORKSHOP HIGH-HEAD
WEIGH TANKS AND LABORATORY
Water Passage
Air Escape Openings in Each Web Wall
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T ENG'R.
TRACED BY:- E.C.A.
SCALE:- 1/8"=1'-0"
FEBRUARY 14, 1931
SHEET No 6



TRANSVERSE SECTION THRU FOREBAY



VERTICAL SECTION
SUPPLY PIPE AND DISCHARGE
PIPE OF LARGE CENTRIFUGAL PUMPS.
Scale 1/4"=1'



TRANSVERSE SECTION THRU EAST END OF BUILDING

GENERAL SPECIFICATIONS COVERING DESIGN OF STRUCTURAL STEEL AND REINFORCED CONCRETE AS ALLOWED FOR IN ACCOMPANYING ESTIMATE OF COST.

1. — All structural steel beams are designed on basis of 16,000 lbs/sq.in. maximum extreme fiber stress under total dead plus assumed live loads.

2. — All steel columns are designed to withstand eccentric loads from floor beams, cranes, etc., with maximum fibre stress not exceeding 16,000 lbs/sq.in.

3 — All concrete structurers are designed on basis of 700 lbs/sq.in. maximum compressive stress.

4 — All concrete reinforcement steel is designed for a maximum tensile stress of 16,000 lbs/sq in. for resisting dead plus assumed live loads.

5 — For resisting shrinkage and temperature stresses, not less than 0.5 of one percent (ratio of steel to concrete, by cross-sectional area) of reinforcing steel has been provided in all cases where walls must retain water.

6 — For all important concrete work, such as basin walls and floors, flume walls and floors, etc. a mixture in proportion 1:1½:3 (cement: sand: aggregate) or equivalent, shall be used.

7 — All concrete materials to be carefully graded and thoroughly mixed, not less than 1½ minutes per. batch, and well tamped and vibrated into place to give a dense, impervious concrete as nearly water-proof as practicable.

8 — Form work to be of extra quality, securely braced to give smooth even surfaces of concrete.

Forms for interior walls of Measuring Basin to be of planed lumber and rigidly held in place to prevent distortion so that finished concrete wall surface shall not be more than 3/4 in. out of alignment in a length of 100 ft. and not more than 1/8 in. out of alignment in a length of 10 feet.

Forms for interior walls of Main and Return Flumes shall be steel, rigidly supported and braced to give finished concrete surface not more than 1/2 in. out of alignment in length of flume, and not more than 1/8 in. out of alignment in any length of 10 feet.

9 — Base of all wall footings are horizontally reinforced for spreading the load over the decomposed rock.

10 — All concrete foundation walls are diagonally reinforced in vertical plane to give added girder strength for distributing load over decomposed rock.

The accompanying Estimate of Cost, based on detailed design, is made up from present scale of contract prices, in conference with the Turner Construction Co. of Philadelphia and Charles T. Main Inc., of Boston with the understanding that the Turner Construction Co. would be ready to submit a lump sum bid for the entire structure at price corresponding.

NOTE: That due to present industrial depression exceptionally low current bids are being made by large contracting concerns desirous of retaining their organization against better times.

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T. ENG'R

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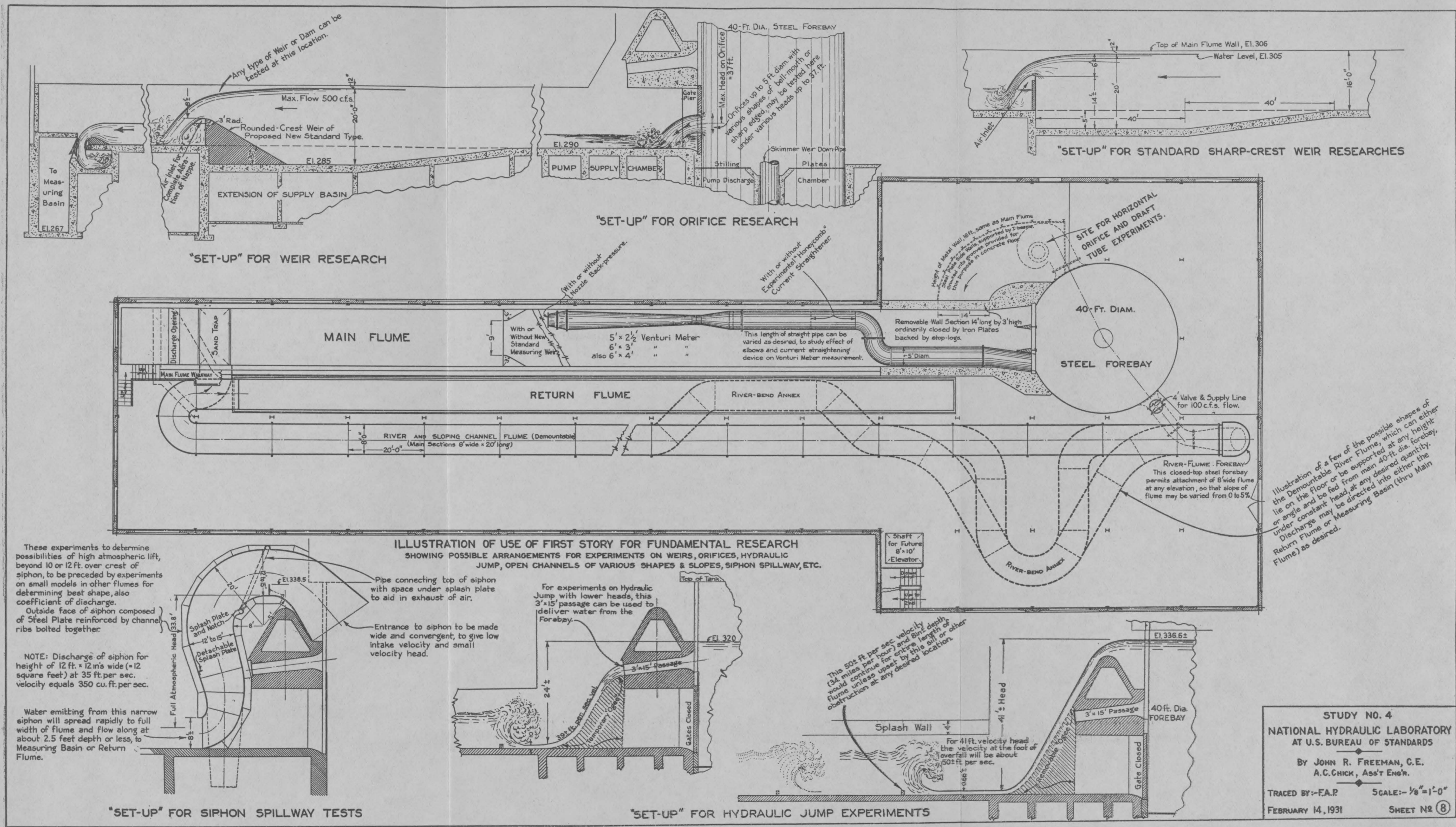
FEBRUARY 14, 1931 SHEET № 7



"SET-UP" FOR WEIR RESEARCH
Any type of Weir or Dam can be tested at this location.
Max. Flow 500 c.f.s.
3' Rad.
Rounded-Crest Weir of Proposed New Standard Type.
Air Inlet for Complete Aeration of Nappe
To Measuring Basin
EXTENSION OF SUPPLY BASIN
El. 285
El. 267
"SET-UP" FOR ORIFICE RESEARCH
40-Ft. DIA. STEEL FOREBAY
Max. Head on Orifice = 37 ft.
Orifices up to 5 ft. diam. with various shapes of bell-mouth or sharp edged, may be tested here under various heads up to 37 ft.
Gate Pier
El. 290
PUMP SUPPLY CHAMBER
Stilling
Skimmer Weir Down-Pipe
Plates
Pump Discharge
Chamber
"SET-UP" FOR STANDARD SHARP-CREST WEIR RESEARCHES
Top of Main Flume Wall, El. 306
Water Level, El. 305
Air Inlet
ILLUSTRATION OF USE OF FIRST STORY FOR FUNDAMENTAL RESEARCH
SHOWING POSSIBLE ARRANGEMENTS FOR EXPERIMENTS ON WEIRS, ORIFICES, HYDRAULIC JUMP, OPEN CHANNELS OF VARIOUS SHAPES & SLOPES, SIPHON SPILLWAY, ETC.
MAIN FLUME
Discharge Opening
SAND TRAP
MAIN FLUME WALKWAY
With or Without New Standard Measuring Weir
(With or without Nozzle Back-pressure.
5' × 2½' Venturi Meter
6' × 3' " "
also 6' × 4' " "
With or without Experimental "Honeycomb" Current Straightener
This length of straight pipe can be varied as desired, to study effect of elbows and current straightening device on Venturi Meter measurement.
5' Diam.
Removable Wall Section 14' long by 3' high ordinarily closed by Iron Plates backed by stop-logs.
SITE FOR HORIZONTAL ORIFICE AND DRAFT TUBE EXPERIMENTS.
40-Ft. DIAM.
STEEL FOREBAY
4' Valve & Supply Line for 100 c.f.s. flow.
RETURN FLUME
River-bend Annex
RIVER AND SLOPING CHANNEL FLUME (Demountable) (Main Sections 8' wide × 20' long)
20'-0"
River-Flume Forebay
This closed-top steel forebay permits attachment of 8' wide flume at any elevation, so that slope of flume may be varied from 0 to 5%.
Illustration of a few of the possible shapes of the Demountable River Flume, which can either lie on the Floor or be supported at any height or angle and be fed from main 40 ft. dia. forebay under constant head, at any desired quantity. Discharge may be directed into either the Return Flume or Measuring Basin (thru Main Flume) as desired.
Shaft for Future 8' × 10' Elevator
RIVER-BEND ANNEX
These experiments to determine possibilities of high atmospheric lift, beyond 10 or 12 ft. over crest of siphon, to be preceded by experiments on small models in other flumes for determining best shape, also coefficient of discharge.
Outside face of siphon composed of Steel Plate reinforced by channel ribs bolted together.
NOTE: Discharge of siphon for height of 12 ft. × 12 in's wide (= 12 square feet) at 35 ft. per sec. velocity equals 350 cu. ft. per sec.
Water emitting from this narrow siphon will spread rapidly to full width of flume and flow along at about 2.5 feet depth or less, to Measuring Basin or Return Flume.
Pipe connecting top of siphon with space under splash plate to aid in exhaust of air.
Entrance to siphon to be made wide and convergent, to give low intake velocity and small velocity head.
El. 338.5
Splash Plate and Notch
Detachable Splash Plate
Full Atmospheric Head 33.8'
"SET-UP" FOR SIPHON SPILLWAY TESTS
For experiments on Hydraulic Jump with lower heads, this 3' × 15' passage can be used to deliver water from the Forebay.
Top of Tank
El. 320
3' × 15' Passage
Gates Closed
"SET-UP" FOR HYDRAULIC JUMP EXPERIMENTS
This 50± ft. per sec. velocity (34 miles per hour) and 8 in. depth would continue for entire length of flume unless upset by this sill or other obstruction at any desired location.
El. 336.6±
41± Head
Splash Wall
For 41 ft. velocity head the velocity at the foot of overfall will be about 50± ft. per sec.
Removable Chute
3' × 15' Passage
40 ft. Dia. FOREBAY
Gate Closed
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R.
TRACED BY:- F.A.P.
SCALE:- 1/8" = 1'-0"
FEBRUARY 14, 1931
SHEET No. 8

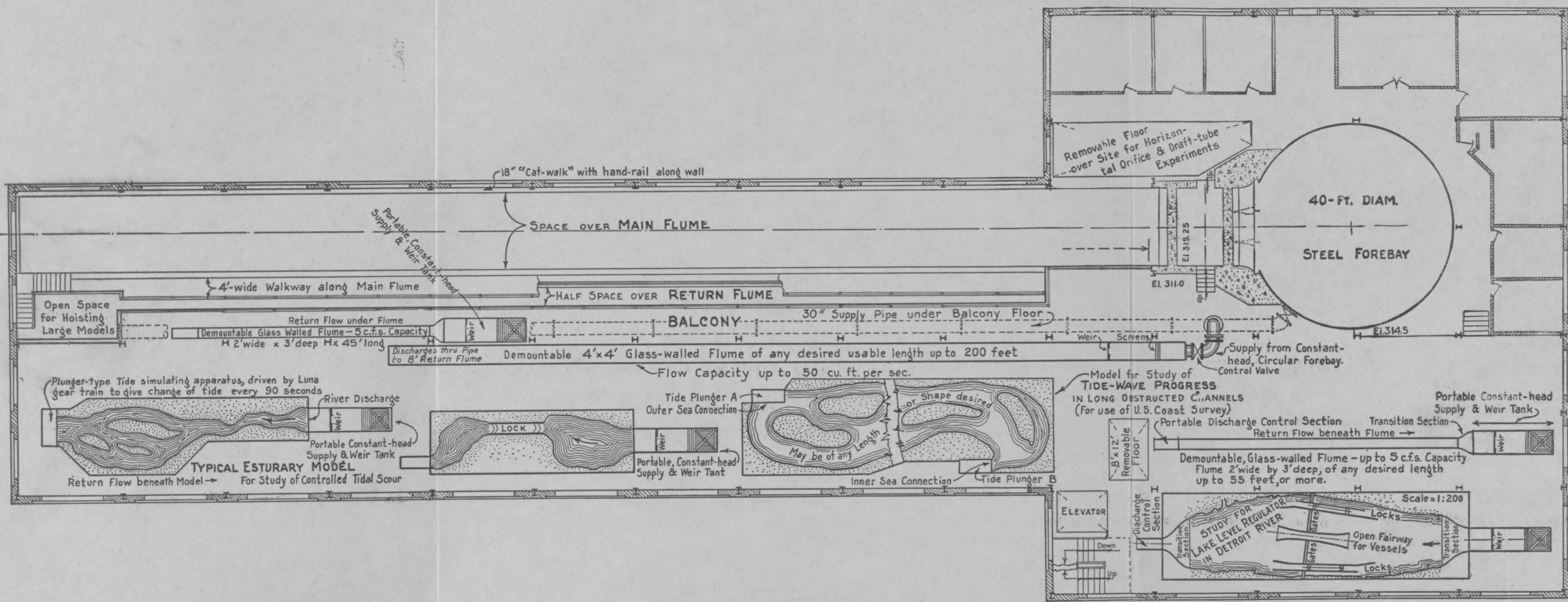


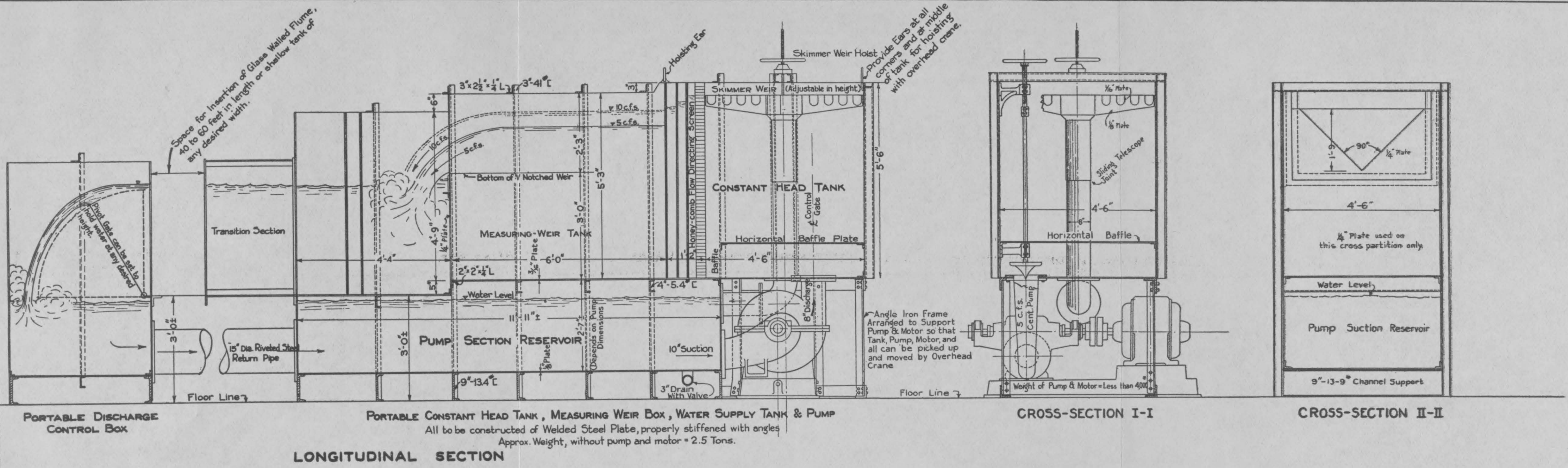
ILLUSTRATION OF USE OF SECOND STORY FOR TEMPORARY "SET-UPS"
SHOWING A HALF-DOZEN RESEARCHES OF ORDINARY TYPE IN PROGRESS SIMULTANEOUSLY
WITH OPEN FLOOR SPACE AVAILABLE FOR SEVERAL MORE RESEARCHES

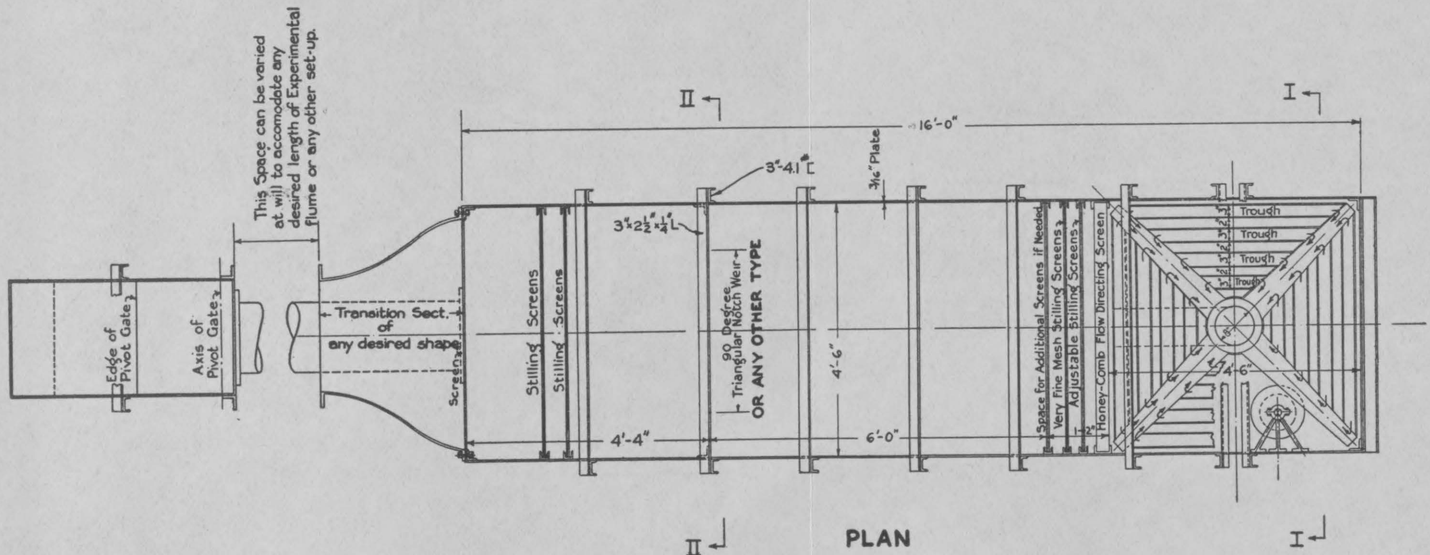
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T ENG'R.

TRACED BY:- SCALE:- 1/8" = 1'-0"

FEBRUARY 14, 1931 SHEET No. 9



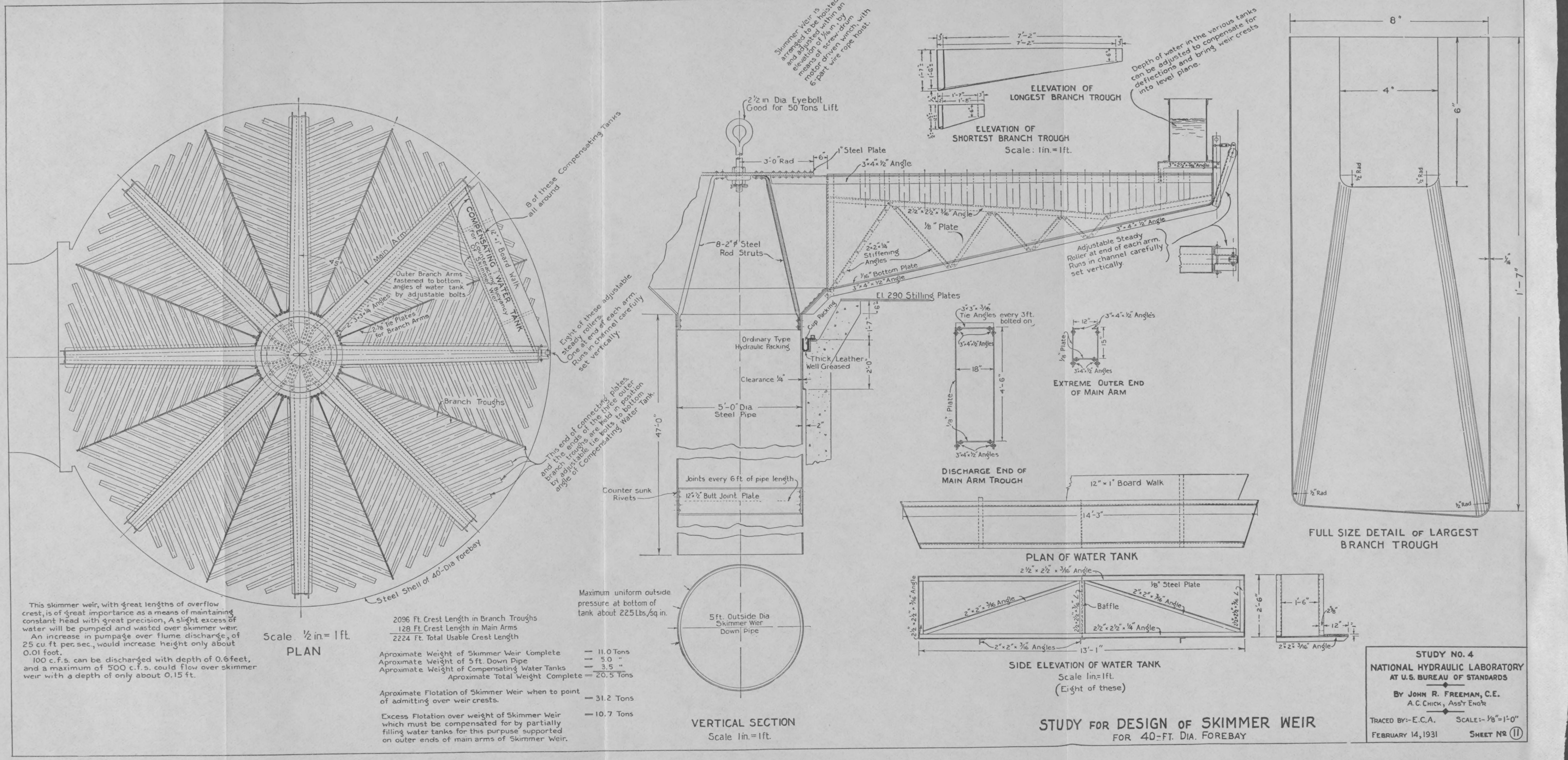


(1) Experiments for determining coefficients with extremely turpid water,
(2) Experiments with Salt Water,
(3) Experiments with water at extreme temperature,
can be made with this independent portable apparatus without disturbing conditions in forebay and large basins

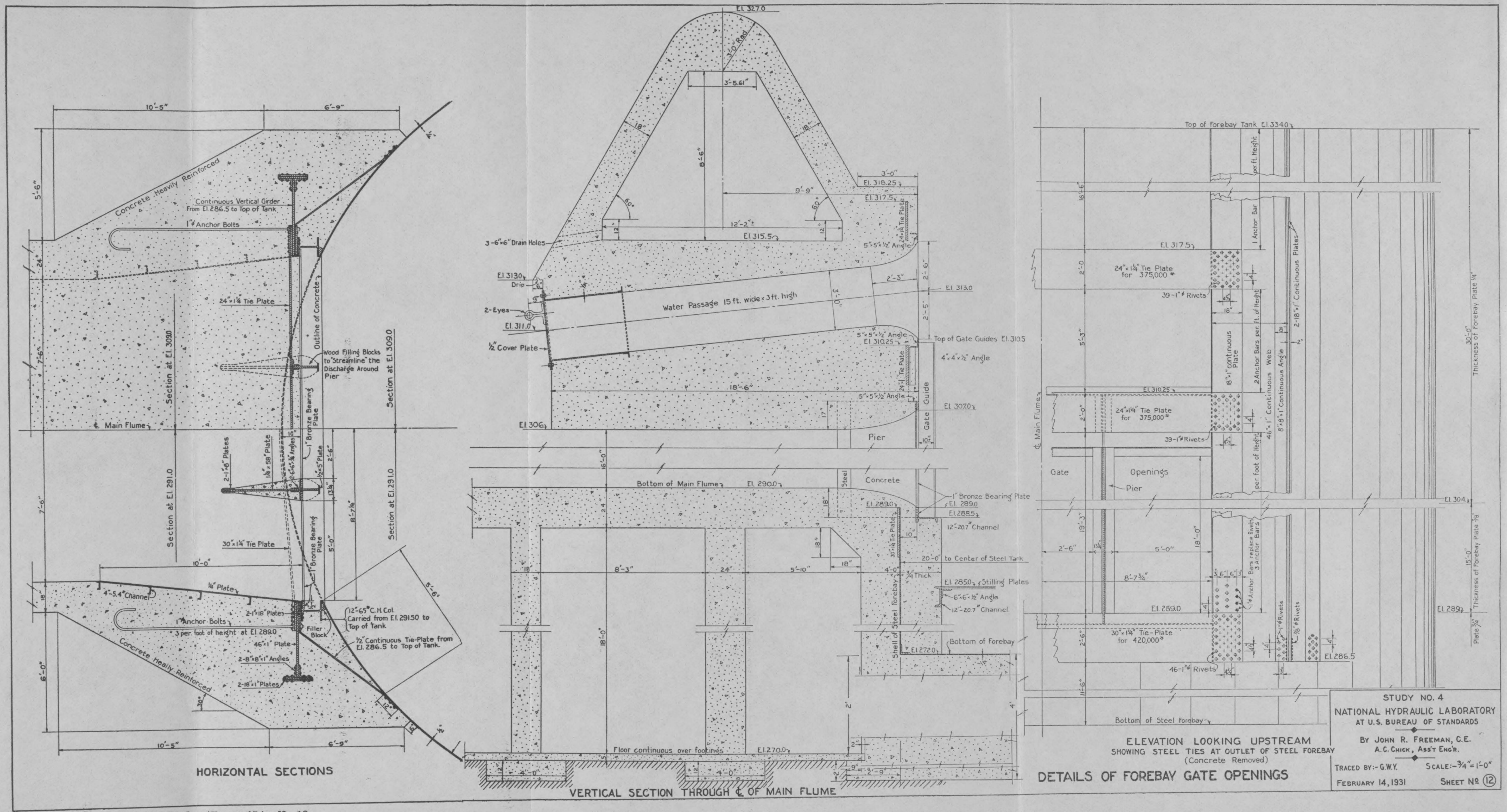
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

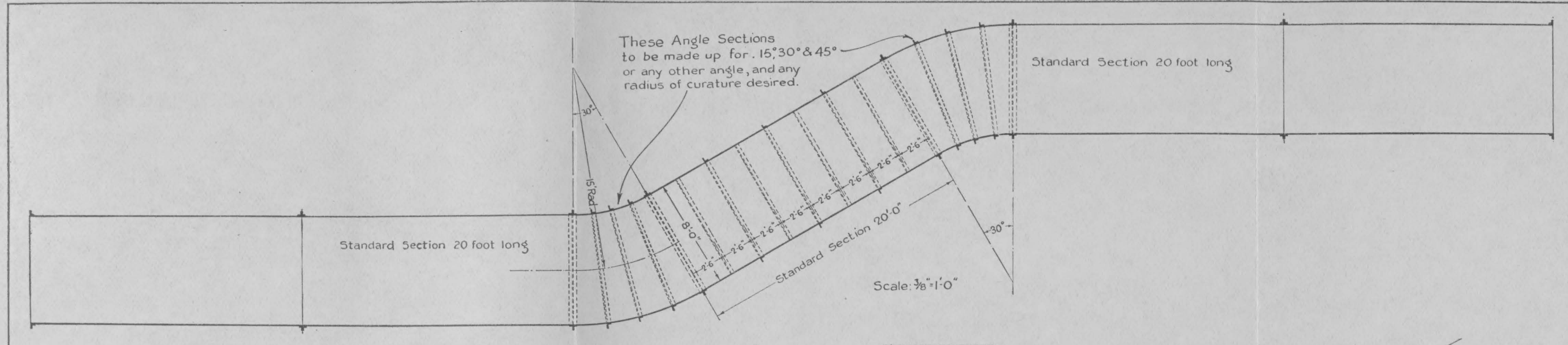
By John R. Freeman, C.E.
A.C. Chick, Ass't Eng'r.

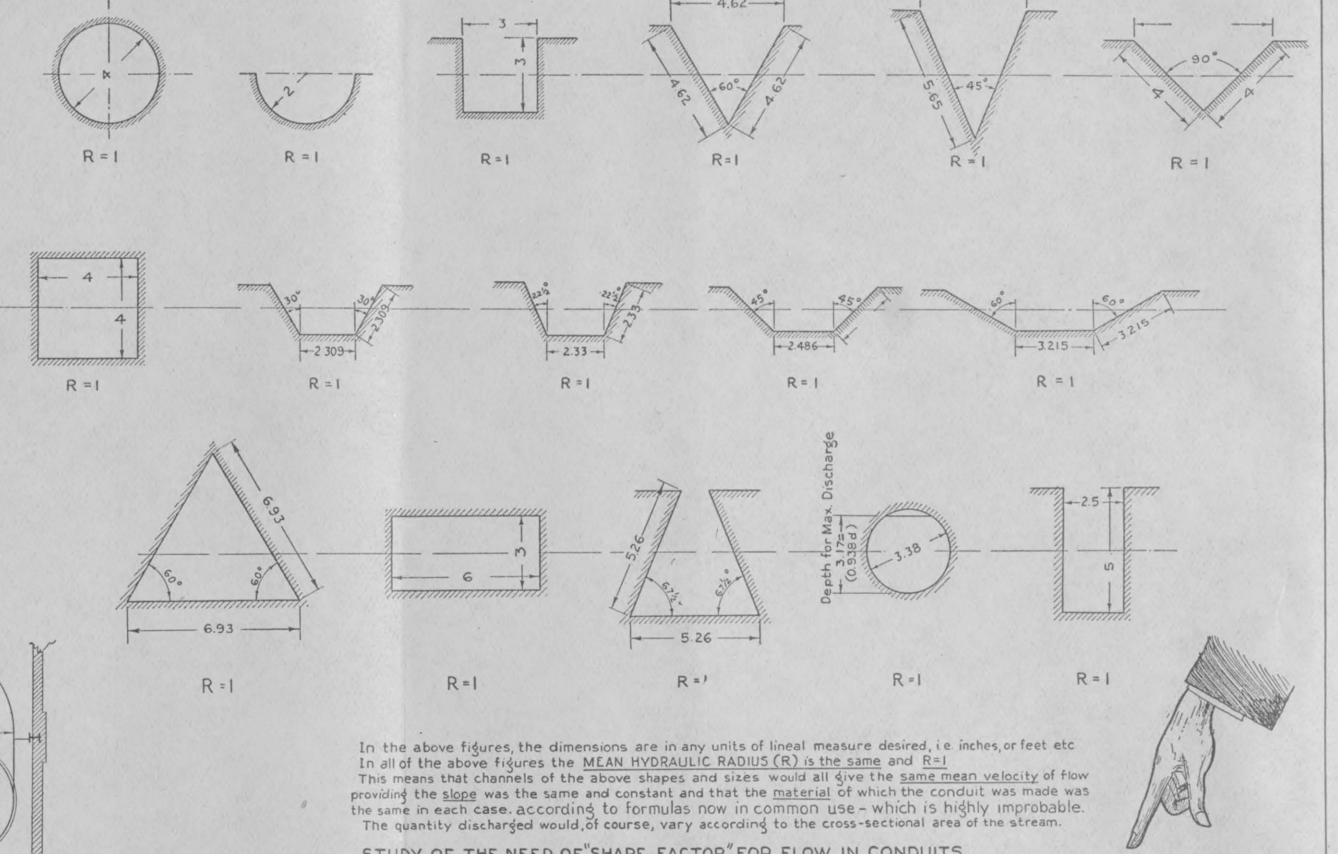
Traced by:- E.C.A. Scale:- 1" = 1'-0"
February 14, 1931 Sheet № 10



STUDY FOR DESIGN OF SKIMMER WEIR
FOR 40-FT. DIA. FOREBAY
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R
TRACED BY:- E.C.A.
SCALE:- 1/8"=1'-0"
FEBRUARY 14, 1931
SHEET Nº 11
PLAN
Scale 1/2 in.= 1 ft.
8 of these Compensating Tanks all around
COMPENSATING WATER TANK
For Counteracting Buoyancy of Skimmer Weir
12"×1" Board Walk
Main Arm
Outer Branch Arms fastened to bottom angles of water tank by adjustable bolts
2"×2"×1/4" Angles
2"×1/8" Tie Plates for Branch Arms
Branch Troughs
Eight of these adjustable steady rollers. One at end of each arm. Runs in channel carefully set vertically.
This end of connecting plates and the ends of the three outer branch troughs are held in position by adjustable tie bolts to bottom angle of Compensating Water Tank.
Steel Shell of 40'-Dia Forebay
This skimmer weir, with great lengths of overflow crest, is of great importance as a means of maintaining constant head with great precision. A slight excess of water will be pumped and wasted over skimmer weir.
An increase in pumpage over flume discharge, of 25 cu ft per sec., would increase height only about 0.01 foot.
100 c.f.s. can be discharged with depth of 0.6 feet, and a maximum of 500 c.f.s. could flow over skimmer weir with a depth of only about 0.15 ft.
2096 Ft. Crest Length in Branch Troughs
128 Ft. Crest Length in Main Arms
2224 Ft. Total Usable Crest Length
Aproximate Weight of Skimmer Weir Complete — 11.0 Tons
Aproximate Weight of 5 ft. Down Pipe — 5.0 "
Aproximate Weight of Compensating Water Tanks — 3.5 "
Aproximate Total Weight Complete — 20.5 Tons
Aproximate Flotation of Skimmer Weir when to point of admitting over weir crests. — 31.2 Tons
Excess Flotation over weight of Skimmer Weir which must be compensated for by partially filling water tanks for this purpose supported on outer ends of main arms of Skimmer Weir. — 10.7 Tons
Skimmer Weir is arranged to be hoisted and adjusted within an elevation of 1/16 in. by means of screw drum motor driven winch, with 6-part wire rope hoist.
2 1/2 in Dia Eyebolt Good for 50 Tons Lift
3'-0" Rad
6"
1" Steel Plate
3"×4"×1/2" Angle
2 1/2"×2 1/2"×3/16" Angle
1/8" Plate
8-2" ϕ Steel Rod Struts
2"×2"×1/4" Stiffening Angles
1/16" Bottom Plate
3"×4"×1/2" Angle
El. 290 Stilling Plates
Cup Packing
Ordinary Type Hydraulic Packing
Thick Leather Well Greased
Clearance 1/4"
5'-0" Dia Steel Pipe
47'-0"
Joints every 6 ft of pipe length
Counter sunk Rivets
12"×1/2" Butt Joint Plate
Adjustable Steady Roller at end of each arm. Runs in channel carefully set vertically.
Depth of water in the various tanks can be adjusted to compensate for deflections and bring weir crests into level plane.
Maximum uniform outside pressure at bottom of tank about 22.5 Lbs./sq. in.
5 ft. Outside Dia Skimmer Weir Down Pipe
VERTICAL SECTION
Scale 1 in.= 1 ft.
ELEVATION OF LONGEST BRANCH TROUGH
7'-2"
ELEVATION OF SHORTEST BRANCH TROUGH
Scale: 1 in.= 1 ft.
3"×3"×3/16" Tie Angles every 3 ft. bolted on
3"×4"×1/2" Angles
18"
4'-6"
1/8" Plate
DISCHARGE END OF MAIN ARM TROUGH
12"
15"
EXTREME OUTER END OF MAIN ARM
12"×1" Board Walk
14'-3"
PLAN OF WATER TANK
2 1/2"×2 1/2"×3/16" Angle
1/8" Steel Plate
2"×2"×3/16" Angle
Baffle
2 1/2"×2 1/2"×1/4" Angle
2"×2"×3/16" Angles
13'-1"
2'-6"
1'-6"
SIDE ELEVATION OF WATER TANK
Scale 1 in.= 1 ft.
(Eight of these)
8"
4"
6"
1'-7"
1/2" Rad
FULL SIZE DETAIL OF LARGEST BRANCH TROUGH

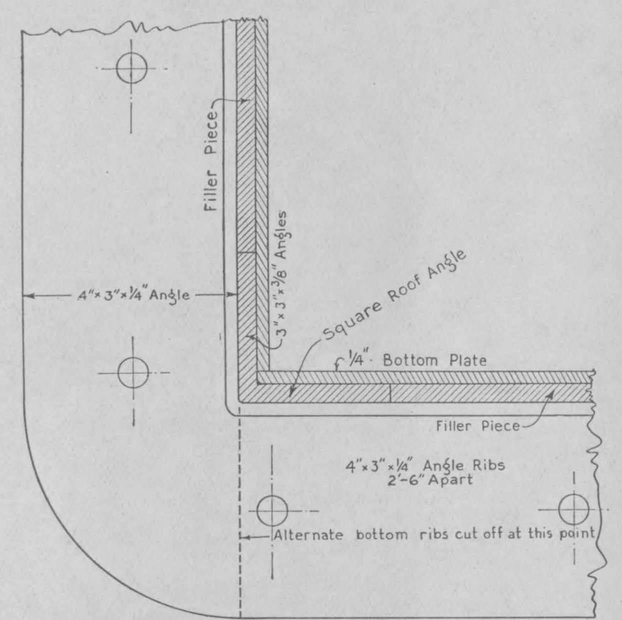

HORIZONTAL SECTIONS
Concrete Heavily Reinforced
Continuous Vertical Girder from El. 286.5 to Top of Tank
1" ⌀ Anchor Bolts
24"×1¼" Tie Plate
Outline of Concrete
Wood Filling Blocks to "Streamline" the Discharge Around Pier
Section at El. 309.0
Section at El. 291.0
℄ Main Flume
1" Bronze Bearing Plate
30"×1¼" Tie Plate
4"-5.4" Channel
¼" Plate
12"-65# C.H. Col. Carried from El. 291.50 to Top of Tank
Filler Block
½" Continuous Tie-Plate from El. 286.5 to Top of Tank.
3 per. foot of height at El. 289.0
VERTICAL SECTION THROUGH ℄ OF MAIN FLUME
El. 327.0
Water Passage 15 ft. wide × 3 ft. high
3-6"×6" Drain Holes
2-Eyes
½" Cover Plate
Top of Gate Guides El. 310.5
Gate Guide
Pier
Concrete
Bottom of Main Flume
1" Bronze Bearing Plate
12"-20.7# Channel
20'-0" to Center of Steel Tank
Stilling Plates
Shell of Steel Forebay
Bottom of Forebay
Floor continuous over footings
El. 270.0
Top of Forebay Tank El. 334.0
24"×1¼" Tie Plate for 375,000#
39-1"⌀ Rivets
18"×1" Continuous Plate
2 Anchor Bars per ft. of Height
46"×1" Continuous Web
8"×8"×1" Continuous Angle
2-18"×1" Continuous Plates
Gate Openings
Pier
30"×1¼" Tie-Plate for 420,000#
46-1"⌀ Rivets
Bottom of Steel Forebay
Thickness of Forebay Plate
ELEVATION LOOKING UPSTREAM
SHOWING STEEL TIES AT OUTLET OF STEEL FOREBAY
(Concrete Removed)
DETAILS OF FOREBAY GATE OPENINGS
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T ENG'R.
TRACED BY:- G.W.Y.
SCALE:- ¾" = 1'-0"
FEBRUARY 14, 1931
SHEET Nº 12



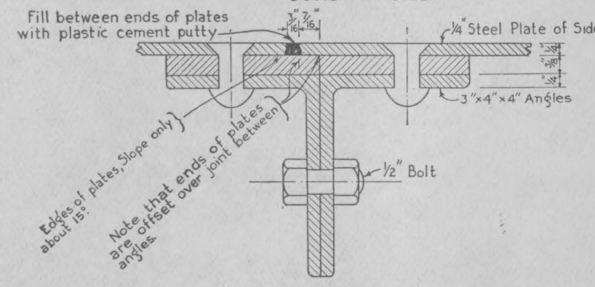


In the above figures, the dimensions are in any units of lineal measure desired, i.e. inches, or feet etc
In all of the above figures the MEAN HYDRAULIC RADIUS (R) is the same and R=1
This means that channels of the above shapes and sizes would all give the same mean velocity of flow providing the slope was the same and constant and that the material of which the conduit was made was the same in each case, according to formulas now in common use - which is highly improbable.
The quantity discharged would, of course, vary according to the cross-sectional area of the stream.

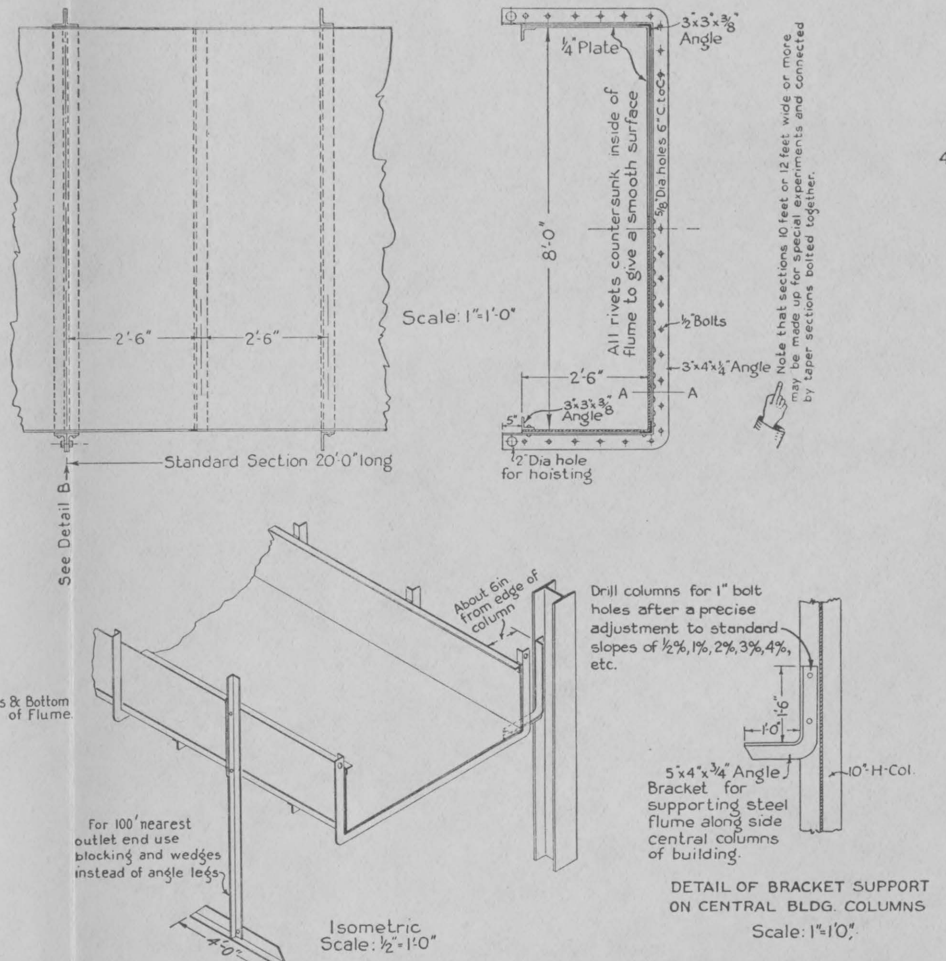
STUDY OF THE NEED OF "SHAPE FACTOR" FOR FLOW IN CONDUITS ESTIMATING



DETAIL OF CONNECTION AT B
Scale Full Size

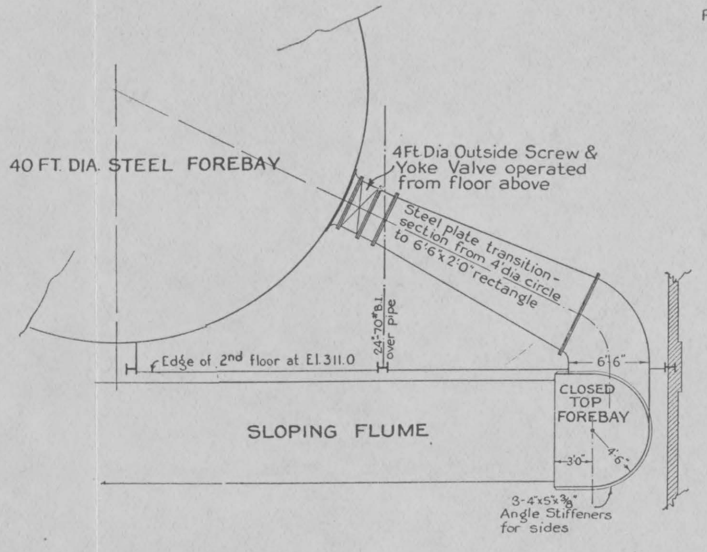


DETAIL OF CONNECTIONS AT A-A
Scale Full Size

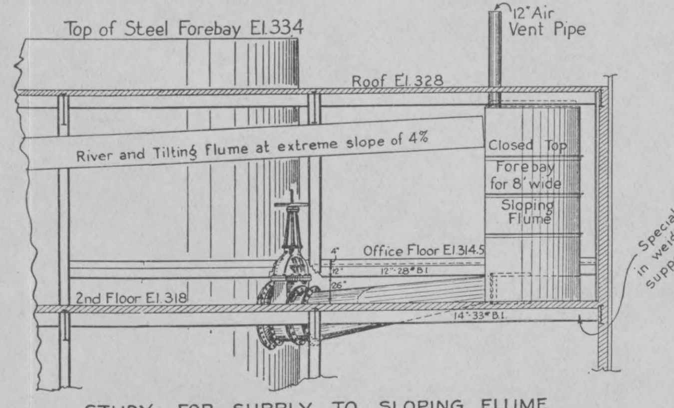


STUDY FOR DESIGN OF 8FT. WIDE SLOPING FLUME
For Many Experiments This Flume Will Lay on Floor.

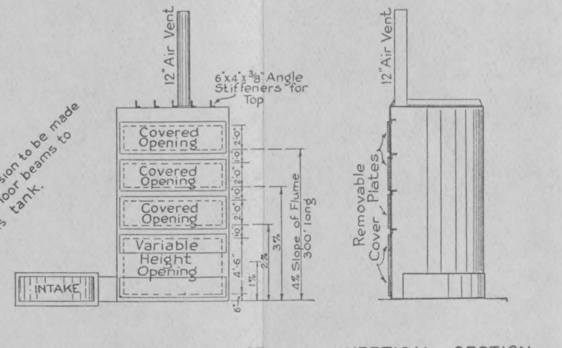
DETAIL OF BRACKET SUPPORT ON CENTRAL BLDG. COLUMNS
Scale: 1"=1'0"



SLOPING FLUME



STUDY FOR SUPPLY TO SLOPING FLUME
(IF LOCATED IN 2nd STORY) May be located in 1st story
Scale: 1"=4'0"



FRONT ELEVATION OF FOREBAY

VERTICAL SECTION THROUGH FOREBAY

Scale: 1"=4'0"

Study No 3 comprised 27 large sheets of outlines and construction details, drawn up for purpose of accurately estimating cost, many of which were not changed for this final Study No 4.

Those drawings comprising details of structural steel, reinforced concrete and various minor details of construction, are not reproduced in this set of 13 sheets comprising J.R.F. Study No. 4

STUDY No. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

By JOHN R. FREEMAN, C.E.
A.C. CHICK, Ass't Eng'r

TRACED BY:- R.B. SCALE:- AS SHOWN
FEBRUARY 14, 1931 SHEET No 13

Facilities for small-scale experimental work: Constant-head supply tanks	First floor: Supply from 40-foot diameter steel forebay, through 30-inch supply line running length of building and available for supplying the second as well as the first story experiments.[24]	First floor: Supply from concrete forebay through 30 and 20 inch pipe line under the first floor. Second floor: One large constant-head tank of 3 compartments for supplying 20, 10, and 10 cubic feet per second, respectively. Third floor: One small constant-head tank of 2 compartments for supplying up to 10 cubic feet per second each.[25]

[20] Test pits very few, borings inconclusive. The term "firm" rock, as used by the Bureau staff in designating the character of the rock upon which they propose to rest the foundations of the building, is misleading. This rock, classified as "firm," is a decomposed granite similar to the overlying decomposed material, but slightly harder, as indicated by greater resistance to penetration by the drill. The two deep test pits were refilled before I had opportunity to personally examine the material *in situ*. I desired opportunity to examine it in conference with Doctor White or other experts from the United States Geological Survey. I have conferred repeatedly with Doctor Stratton about foundation conditions found at the present Bureau buildings built under his supervision, and have studied supposedly similar material at excavations in the vicinity. Samples, taken at the elevation of this so-called "firm" rock, after having been exposed to the atmosphere a few weeks, present only slightly different characteristics from the so-called decomposed rock at 8 or 10 feet higher elevation. Samples from both elevations are readily crumbled in one's fingers, and present a more or less granular appearance. In no case does it appear that foundations as proposed by the Bureau staff, will reach really "solid" rock that is not more or less decomposed. It appears from inspection of near-by quarries in this vicinity, and information from engineers and architects acquainted with the material, that the underlying rock below the layer of decomposed material, is broken into relatively small, irregular sharp-edged blocks with fault planes running in all directions. That these blocks of rock may be subject to movement along cracks and joint planes, is indicated by experiences at the new power house. The Bureau's plant engineer states that the power house is founded on this so-called "solid" rock, movement of which has already caused serious cracking of the floors and walls near the east end of this building, such that he believes an overlying cushion of the decomposed rock gives better support. This decomposed rock is a rather dense, closely packed material capable of supporting more than ordinary earth material. It is not subject to slippage. One should not be misled by a casual inspection of the natural ground surface which is a clayey loam and quite slippery when moist. In view of the above conditions it seems logical and wise to keep the foundations on a cushioning layer of the decomposed rock, and that any expense involved in carrying the foundation walls 10 to 15 feet deeper than the structure itself requires, is a needless waste of money that is very urgently needed in the building and equipment.

[21] The ground covered by the Bureau is shown by size of trees to be in the same state (free of dumped material) as when Bureau of Standards was established. The weight removed by excavation to foundation bottom will be greater than that imposed by the new structures; therefore, no settlement is to be feared, if bottom course is properly placed. Actual load on earth in nearly all places will be smaller than it has carried for perhaps thousands of years. The concrete foundation walls of J. R. Freeman design to be specially reinforced for distributing loads. Concrete foundation walls contain a very large amount of reinforcing steel designed to cause them to act as strong girders in distributing the load.

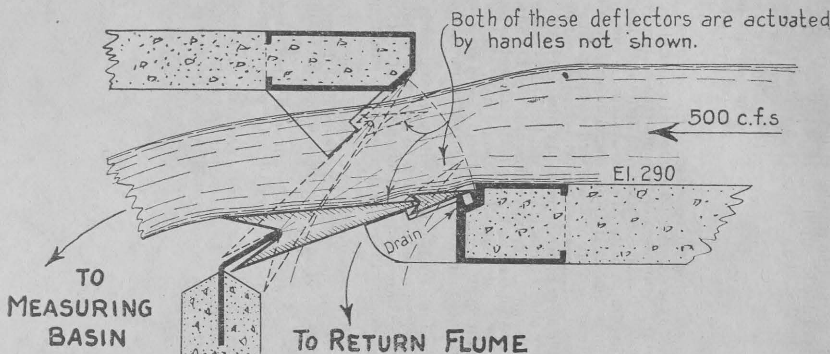
[22] Open access for research.

[23] J. R. Freeman regards it highly desirable that the large centrifugal pump be so placed and so provided with windows for observations on cavitation and turbulence that it can add important practical knowledge helpful to the theory and improvement of such pumps, and regards it extremely desirable that the detailed design of the large pumps be deferred for a year or more until researches can be made with small-model pumps, analogous to those made on models of ship propellers, which are resulting in great improvement in efficiency.

[24] It is proposed to provide several portable individual, self-contained, constant-head tanks and measuring weir boxes, with pump and supply reservoir combined. These units can readily be moved by crane to any desired location. Constant-head tanks of a permanent nature can be provided at any time if it is found desirable, much the same as those proposed in the Bureau design.

[25] It is understood that one or two of the individual constant-head units (self-contained and portable) as proposed by John R. Freeman, are being considered as desirable pieces of equipment. One undesirable feature of the layout of permanent constant-head tanks as proposed in the Bureau design is that when the units in the third story are being used, one or more of the compartments of the second story constant-head tank are rendered more or less useless for experimental work because of the fact that they are used as supply basins for the third floor pumps.

It seems plain to John R. Freeman, from inspection, that the Bureau of Standards' design No. 2 per plans of February 3, 1931, contained so much more concrete and intricate form work, that it will be more costly (possibly $50,000 in excess of John R. Freeman's design No. 4), and therefore that it will have to be cut greatly from plans as sketched on February 3, thereby rendering the laboratory of the Bureau's design still more inferior in capacity for large-scale fundamental research to the John R. Freeman design.



DIAGRAMMATIC ILLUSTRATION OF THE QUICK-SWINGING DIVERTING GATE AT END OF MAIN FLUME